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The Drilling Fluid Hazard Assessment Program of the U.S. Environmental Protection Agency

Mitre Corp.
McLean, VA

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Summary of the Drilling Fluid Hazard Assessment Program

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2.0 STATUTORY AND REGULATORY MANDATES

Several Federal agencies have mandates involving the protection of the marine environment through the regulation and planning of the development of offshore oil and gas resources. These Federal agencies include:

- Environmental Protection Agency
- National Oceanic and Atmospheric Administration
- Bureau of Land Management
- Geological Survey

The U.S. Environmental Protection Agency has the responsibility to issue permits for discharges from drilling and production platforms under the National Pollutant Discharge Elimination System (NPDES) program. There are several regulated discharges:

- Drilling fluids - chemicals ("muds") used in the well during drilling
- Cuttings - solid materials from the geological formation being penetrated by the well that are brought to the surface as drilling proceeds
- Produced waters - liquids (often a brine) from the geological formation that come to the surface in the well and which are discharged after separation from the oil and gas
- Other miscellaneous discharges - these can include sanitary wastes, deck drainage, and cooling water.

The authority for EPA regulatory activities over discharges to aquatic environments is contained in Sections 402 and 403 of the Clean Water Act (see Appendix B for the text of these sections). This authority has been extended to the waters of the continental shelf under the provisions of the Outer Continental Shelf Lands Act Amendments.

Authority for issuing NPDES permits is contained in Section 402 of the Clean Water Act. The conditions established for these permits are to be based on technical guidelines required under provisions of Section 403(c)(1). The kinds of information that the guidelines must contain are defined in this section. The guidelines have been

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16. ABSTRACT

The Drilling Fluids Hazard Assessment Program carried out by the Office of Research and Development of the Environmental Protection Agency is presented, from its initiation in 1976 to the planned tasks for Fiscal Year 1982.

This synopsis includes discussions on program origins, statuatory mandates, program goals and objectives and the rationale and strategy for the research conducted. A summary of the research results to date and the direction of the final year of the program is included.

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TABLE OF CONTENTS

		Page
	LIST OF TABLES	vii
	LIST OF FIGURES	viii
1.0	INTRODUCTION	1-1
1.1	Statement of the Problem	1-1
1.1.1	Discharges from Offshore Oil and Gas Platforms	1-1
1.1.2	Purpose and Composition of Drilling Muds	1-3
1.1.3	State of Knowledge Concerning Drilling Fluids Prior to Initiation of the EPA Program	1-4
1.1.4	Need for an EPA Research Program	1-5
1.2	Organization of Summary	1-6
2.0	STATUTORY AND REGULATORY MANDATES	2-1
3.0	EPA RESEARCH PROGRAM	3-1
3.1	Program Goals and Objectives	3-1
3.2	Research Approach	3-1
3.2.1	Components of a Hazard Assessment	3-2
3.2.2	Tiered Approach of Research	3-2
3.2.3	Selection of Drilling Fluids Used in Effects Assessment Research Projects	3-3
3.2.4	Rationale for Testing of Individual Mud Components	3-5
3.3	EPA Research Program	3-5
3.3.1	Generic Studies	3-6
3.3.2	Flower Garden Banks, Gulf of Mexico	3-14
3.3.3	Georges Bank, Gulf of Maine	3-21

TABLE OF CONTENTS (Concluded)

	Page
4.0 RESEARCH RESULTS TO DATE	4-1
4.1 Introduction	4-1
4.2 Exposure Assessment	4-1
4.2.1 Field Studies of Discharge Plume Dispersion	4-2
4.2.2 Models of Plume Dispersion	4-3
4.2.3 Sedimentation and Monitoring Studies	4-3
4.3 Effects Assessment	4-4
4.3.1 Pentachlorophenol Tests	4-4
4.3.2 Short-Term Toxicity Tests	4-5
4.3.3 Long-Term Toxicity Tests	4-8
4.3.4 Bioaccumulation Studies	4-9
4.3.5 Effects on Benthic Communities	4-10
4.3.6 Effects on Corals	4-11
4.4 Summary	4-13
5.0 FUTURE DIRECTION OF THE EPA PROGRAM	5-1
5.1 Factors Affecting the Final Year of the EPA Program	5-1
5.2 Strategy for the Final Year of the Program	5-2
APPENDIX A - PROJECT DESCRIPTIONS	A-1
GENERIC STUDIES	A-2
FLOWER GARDEN BANKS	A-19
GEORGES BANK	A-37
APPENDIX B - SECTIONS 402 AND 403 OF THE CLEAN WATER ACT	B-1
APPENDIX C - CALCULATION OF VOLUME OF DRILLING MUD DISCHARGED TO THE MARINE ENVIRONMENT DURING 1980	C-1
REFERENCES	D-1

LIST OF TABLES

TABLE NUMBER		PAGE
3-1	SOURCE OF SOME DRILLING FLUIDS USED IN RESEARCH SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY	3-4
3-2	AGGREGATED SUMMARY OF MAIN RESEARCH AREAS OF THE DRILLING FLUID HAZARD ASSESSMENT PROGRAM	3-7
3-3	PROJECT SCHEDULES FOR GENERIC STUDIES OF FATE AND EFFECTS OF DRILLING FLUIDS IN THE MARINE ENVIRONMENT	3-8
3-4	PROJECT SCHEDULES FOR STUDIES OF FATE AND EFFECTS OF DRILLING FLUIDS ON THE FLOWER GARDEN BANKS, GULF OF MEXICO	3-16
3-5	PROJECT SCHEDULES FOR STUDIES OF FATE AND EFFECTS OF DRILLING FLUIDS ON GEORGES BANK, GULF OF MAINE	3-22

LIST OF FIGURES

FIGURE NUMBER		PAGE
1-1	TRACTS PROPOSED FOR OIL AND GAS EXPLORATION AND DEVELOPMENT	1-2
5-1	RESEARCH STRATEGY FOR THE FINAL YEAR OF THE DRILLING FLUIDS HAZARD ASSESSMENT PROGRAM	5-3

1.0 INTRODUCTION

The purpose of this report is to provide an overview of the Drilling Fluids Hazard Assessment Program being carried out by the Office of Research and Development of the U.S. Environmental Protection Agency. Included is a synopsis of the program origins, legislative mandates, program goals and objectives, research rationale and strategy, summary of some research results to date, and direction of the program for the final year.

The Drilling Fluid Hazard Assessment Program was conceived in 1975 in response to the King-Muir Report Drilling Fluid Hazard Assessment Program (King and Muir, 1974) in which was examined the environmental issues associated with more rapid development of oil and gas resources in offshore areas of the United States. The program was given added importance by the need for a technical data base to support the issuance of discharge permits as required in the Clean Water Act when this authority was extended to offshore areas by the Outer Continental Shelf Lands Act. Funds for the program were provided in 1976 and the first research grants awarded in 1977. At present, the program is scheduled to end in 1982.

1.1 STATEMENT OF THE PROBLEM

As the quantity of foreign crude oil imported into the United States has risen rapidly over the past decade, the search for additional domestic sources of oil and gas has intensified. This search has been increasingly focused on the continental shelf with the result that many areas have been proposed for leasing by the Department of the Interior (Figure 1-1). While some of these areas, such as the Gulf of Mexico, have experienced extensive drilling activity in the past, most have not. Under the provisions of the Clean Water Act and the Outer Continental Shelf Lands Act Amendments, the U.S. Environmental Protection Agency must issue permits for the discharge of materials from offshore oil and gas drilling and production platforms. A technical data base is required as the basis for the discharge conditions established in the permit.

1.1.1 Discharges From Offshore Oil and Gas Platforms

Principal among the discharges from offshore oil and gas platforms are fluids used during well drilling, commonly called drilling muds. These muds are used in large volume. For example, during 1979, 1.5 to 5.5 million m^3 (2 to 7 million yd^3) of drilling mud were used in off-shore drilling activities (see Appendix C). About 90 percent of this volume was discharged from platforms in the Gulf of Mexico off Texas and Louisiana, where most offshore drilling is presently taking place. This compares in volume to the average of

KEY

ATLANTIC COAST

1. NORTH ATLANTIC
2. MID-ATLANTIC
3. SOUTH ATLANTIC AND BLAKE PLATEAU

GULF OF MEXICO

4. EAST GULF
5. CENTRAL GULF
6. WEST GULF

PACIFIC

7. SOUTHERN CALIFORNIA BORDERLAND
8. SANTA BARBARA
9. NORTH AND CENTRAL CALIFORNIA
10. WASHINGTON-OREGON

ALASKA

11. COOK INLET (STATE-FEDERAL)
12. SOUTHERN ALEUTIAN SHELF
13. GULF OF ALASKA
14. BRISTOL BAY
15. BERING SEA SHELF
16. BEAUFORT SEA
17. CHUKCHI SEA

FIGURE 1-1
TRACTS PROPOSED FOR OIL AND GAS EXPLORATION AND DEVELOPMENT

about 6 million m^3 (about 8 million yd^3) of dredged material from New York Harbor disposed of annually at the designated ocean disposal site in the New York Bight. During the drilling period at an average platform location, about 1500 to 4500 m^3 (about 2000 to 6000 yd^3) of drilling mud may be used in drilling up to 40 wells. Drilling fluids are released as relatively small-volume operational discharges and as infrequent large-volume bulk discharges.

1.1.2 Purpose and Composition of Drilling Muds

Mud used in offshore drilling is a mixture consisting principally of barite, water and chemical additives, which is pumped into the well through the drill pipe and drill bit. The mud serves a number of purposes:

- Cooling of the rapidly rotating drill bit
- Lubrication of the string of drilling pipe as it turns in the wellbore
- Carrying of rock cuttings to the surface
- Formation of a plaster on the sides of the hole to prevent the formation from crumbling or collapsing into the well and to prevent loss of fluid to the formation
- Providing hydrostatic pressure to prevent formation fluids from entering the well and to control pressures in the well.

A wide variety of chemical ingredients are used to formulate drilling muds. These can include:

- biocides
- pH control products
- calcium removers
- corrosion inhibitors
- deformers
- emulsifiers
- filtrate reducers
- flocculants
- foaming agents
- lost circulation materials
- lubricants
- shale-control inhibitors
- surface-active agents
- thinners
- dispersants
- viscosifiers
- weighting agents

The chemical composition of drilling muds can vary greatly. Muds are often custom formulated for conditions encountered at each well and even for conditions encountered at different depths in a specific well. Additionally, the chemical properties of a mud may be altered by the physical conditions encountered in a well and by materials gained as the well is drilled.

1.1.3 State of Knowledge Concerning Drilling Fluids Prior to Initiation of the EPA Program

Although relatively large amounts of money have been spent by several Federal agencies on research related to the effects of development of oil and gas resources on the outer continental shelf, comparatively few studies have been undertaken to evaluate the effects of discharges of drilling fluids from platforms. When the EPA Drilling Fluids Hazard Assessment Program was conceived in 1975, considerable research was underway on the potential effects of more rapid development of offshore oil and gas resources. At that time, however, environmental concern was focused principally on the effects of petroleum in the marine environment. Only a few studies had been undertaken to examine the toxicity of drilling fluids, cuttings, and produced waters routinely discharged from offshore platforms. Most of the information available was published only as project reports ("gray" literature) which generally had not been subject to a peer-review process for confirmation of the findings. Few data were available in the peer-reviewed journal literature.

Despite this scanty data base, there was a general lack of concern at that time over the potential effects of drilling mud and produced waters discharged in the marine environment. This feeling was based primarily on some commonly held assumptions. The general assumptions about the potential effects of produced waters (Koons et al., 1976) were that:

- their toxicity was low
- natural dilution on discharge greatly reduced the environmental concentrations of hydrocarbons and inorganic components.

General assumptions regarding the consequences of the discharge of drilling fluids (Monaghan et al., 1976) were that:

- bioassay data indicated that any acute toxicity for a typical drilling mud would be due mainly to the dissolved lignosulfonate thinner
- rapid dispersion and dilution quickly lowered the concentrations below those found to be toxic in bioassay tests
- dispersion model calculations indicated that bulk mud discharged at a rates of 250 bbl/hr was diluted one-hundred fold 0.2 mile down-current in less then 1 hour

- both measurements and theoretical calculations indicated that mud discharged during normal drilling quickly mixed with seawater and was diluted at least a thousand fold about 300 yards down current

- discharges had not caused long-lasting effects, as a wide variety of motile organisms were found on and under oil producing platforms

- divers found barnacles growing on and in the exit of discharge pipes

- drilling mud and cuttings from more than 19,000 wells had reportedly not caused detectable environmental damage

- material added in greatest amounts to drilling muds was barite ($BaSO_4$), which was considered to be nontoxic.

1.1.4 Need for an EPA Research Program

In 1975, EPA personnel determined that an inadequate data base existed on the effects of discharges of drilling fluids from offshore platforms. The basis for this finding was that:

- few data were available to support the general lack of concern over the environmental effects of drilling fluids

- drilling fluids contain components such as biocides and heavy metals that are potentially toxic in the environment

- the environmental effects of many drilling fluid components were unknown

- large volumes of drilling fluids are discharged to the environment

- large oceanic areas could potentially be affected.

Based on the need for information to establish the transport, fate and effects of drilling fluids in the marine environment, it was determined that the EPA Drilling Fluids Hazard Assessment Program should be undertaken.

The need for an adequate technical data base on drilling fluid effects was given added importance by the Outer Continental Shelf Lands Act, which extended the Clean Water Act to discharges on the outer continental shelf. EPA must issue permits for the discharge of effluents to aquatic environments under the provisions of Section 402

of the Clean Water Act. The permit process required a base of scientific information on which to establish defensible and reasonable permit conditions.

1.2 ORGANIZATION OF SUMMARY

This program summary is organized into four section. EPA responsiblities as given in the Clean Water Act and the Outer Continental Shelf Land Act Amendments are given in Section 2.0. A discussion of program goals and objectives, the research approach, and the research program is given in Section 3.0. A brief overview of research findings at the present time is given in Section 4.0. The direction of research in the final year of the program is outlined in Section 5.0.

published as ocean dumping criteria (40 CFR Part 125). No permit will be issued if insufficient information exists regarding the potential effects of the discharge (Section 403(c)(2)), emphasizing the importance of research on which to base permit conditions.

3.0 EPA RESEARCH PROGRAM

3.1 PROGRAM GOALS AND OBJECTIVES

The goal of the EPA Drilling Fluids Hazard Assessment Program is to assess what effect the discharge of drilling fluids is likely to have on the marine environment. This information will serve as the basis for determining discharge permit conditions, as required in the Clean Water Act.

Research results related to the program goal will partially provide a basis for the Agency to address the following major questions important to the permit issuance process:

- Are there any significant adverse affects that can result from the discharge of drilling fluids to the marine environment?
- What are the causes if significant effects occur?
- How can effects be mitigated?
- What are the environmental tradeoffs associated with the regulatory options available to the Agency?

The research program as presently constituted is addressing only the first two issues.

Specific objectives of the Drilling Fluids Hazard Assessment Program are as follows:

- Undertake a hazard assessment, which consists of the integration of exposure assessments and effects assessments
- Determine the generic effects of drilling fluids in the marine environment
- Develop region-specific research programs utilizing the hazard assessment approach
- Assemble, review, and synthesize available literature on drilling fluids in the marine environment.

3.2 RESEARCH APPROACH

EPA research is designed to assess the potential hazard to the marine environment and humans from drilling discharge practices. Such a hazard assessment is the integration of knowledge of concentrations of drilling fluids that could occur in the environment under

specific conditions (exposure assessment) and the effect of these concentrations during the period of exposure on marine ecosystems and organisms (effects assessment).

3.2.1 Components of a Hazard Assessment

In general, an exposure assessment would consist of investigations to define the following:

- characteristics of drilling muds
- dilution, transport, and fate of drilling muds
- concentrations of muds extant in the environment
- resuspension and movement of muds following deposition.

An effects assessment should define:

- acute toxicity
- chronic toxicity (carcinogenic, mutagenic, teratagenic properties)
- sublethal effects
- potential for bioaccumulation in components of the food web
- habitat alteration
- effects on ecosystem structure and function
- hazard to humans.

3.2.2 Tiered Approach of Research

The hazard assessment, using exposure assessment and effects assessment as the research approach, has been implemented in the EPA program as a tiered process. In general, laboratory-oriented toxicity tests are undertaken as the first phase. These were usually acute static toxicity tests designed to determine the range of concentrations of drilling fluids that affect organisms. Next, more realistic flow-through toxicity tests are conducted. Field studies of effects are deferred until a need for them is established. In other words, if no significant effects on marine organisms can be detected in laboratory experiments using high concentrations of drilling fluids, determination of effects at lower concentrations likely to occur in the environment are unnecessary, or at least of

low priority. Some aspects of the exposure assessments involving transport and dispersion experiments were scheduled for a later program phase for the same reason.

3.2.3 Selection of Drilling Fluids Used In Effects Assessment Research Projects

An important scientific consideration in the selection of muds for use in toxicity tests has been that the sample be fresh. Practical considerations that have influenced the selection of muds have been the proximity of the well to EPA laboratories and EPA researchers, the availability of muds, and other factors related to the logistics of obtaining samples. The result has been that muds were generally obtained in a manner partially determined by circumstances at the time muds were needed for study.

Mud samples used in the EPA program were selected in cooperation with a number of oil companies, the Petroleum Equipment Suppliers Association, and the Offshore Operators Committee.* Some samples were selected and collected by oil industry personnel and shipped directly to the researchers or to the EPA Gulf Breeze, Florida Laboratory, from which they were transhipped as needed to the researchers. Other samples were collected directly by EPA personnel and supplied to the researchers. In addition, some researchers, through their own initiative, obtained some mud samples outside usual supply channels of the EPA program. The sources of some of the muds used in the program are given in Table 3-1. Additionally, tests are being conducted using a reference mud prepared by the U.S. National Bureau of Standards (see section 3.3.1.1.1).

Mud samples were handled as expeditiously as possible. Short-term storage immediate after collection varied depending on who made the collection. Treatment of samples not collected by EPA were the responsibility of whomever collected them. Samples for biological testing maintained at the EPA Gulf Breeze, Florida Laboratory were kept cool or refrigerated until distributed to researchers.

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*A controversy has arisen over the use of the muds obtained from the MOBIL well in Mobile Bay, Alabama. The drilling permit from the State of Alabama for this well did not allow the discharge of drilling muds to Mobile Bay. Consequently, mud from this well was collected in barges and disposed of on land. These particular muds may be considered atypical of OCS discharged muds because some samples contained oil and/or high levels of chrome lignosulfonate. At present, muds from other wells to be drilled in the same geological formation in Mobile Bay are being considered for ocean disposal.

TABLE 3-1

SOURCE OF SOME DRILLING FLUIDS USED IN RESEARCH
SPONSORED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY

WELL OPERATOR	SUPPLIER OF MUD	WELL LOCATION
	USGS	Louisiana
	USGS	Louisiana
AMOCO	Artique	Florida
MOBIL	Ayres/Ray	Louisiana
SHELL	Ayres/Ray	Louisiana
EXXON	Ayres/Ray	Louisiana
MOBIL	Hellis	Alabama
EXXON	Ayres	New Jersey
EXXON	Yowell	Florida

Mode of transportation and shipment conditions varied depending on the person shipping the sample. Oil company personnel were responsible for shipping conditions for samples shipped directly to researchers or to EPA. Samples shipped to researchers by EPA were generally sent unrefrigerated by the United Parcel Service.

Samples were sometimes stored in a refrigerator at the EPA Gulf Breeze Laboratory for longer periods until needed by researchers. A study found that there were no differences in toxicity between fresh samples and those stored under refrigeration for long periods (Rao, personal communication).

3.2.4 Rationale for Testing of Individual Mud Components

Toxicity studies have been carried out on individual drilling mud components known to be used in offshore drilling. These components have included biocides, barite, diesel fuel, clay, and compounds of zinc and chromium. Testing of single components of muds may help identify those parts that are toxic. A disadvantage of component testing is that, under drilling conditions, these components may react with other components of the mud or be altered so that toxicity could be different than that determined from testing unused mud components.

3.3 EPA RESEARCH PROGRAM

Research has been undertaken at a generic level and within two lease areas of special concern in order to meet the general and site-specific information needs of the EPA program offices and regions in establishing discharge permit conditions. The lease areas are:

- Flower Garden Banks, Gulf of Mexico
- Georges Bank, Gulf of Maine.

These areas were chosen for study over other proposed lease areas (see Figure 1) because:

- drilling would occur in areas thought to be more biologically sensitive than other lease areas
- the areas had been proposed as marine sanctuaries under the Marine Protection, Research, and Sanctuaries Act
- the areas represented different temperature environments
- no drilling had ever taken place on Georges Bank, while the Gulf of Mexico was an established drilling area.

An aggregated summary of program areas is given in Table 3-2.

3.3.1 Generic Studies

Generic studies have been undertaken in both the effects and exposure assessment areas. Project schedules and total funding are given in Table 3-3.

3.3.1.1 Exposure Assessment

Generic exposure assessment studies have involved the characterization of drilling muds and development of models for use in predicting drilling mud transport and dispersion in the marine environment.

3.3.1.1.1 Characterization of Drilling Muds. Because of the wide variation in drilling mud composition, analyses of used muds to which organisms have been exposed must be carried out in support of effects assessment research. Additionally, reference drilling muds of known chemical composition are needed for comparative toxicity testing and for use as chemical standards for quality assurance in analyzing used muds.

Project Title: Drilling Fluid Reference Standards for Chemical Analysis (A-3*) - Develop and provide drilling fluid reference standards for use in characterization efforts and in a quality assurance program to improve and maintain reliability of measurements made on discharges from drilling and production operations.

Project Title: Chemical Analysis of Drilling Fluids (A-4*) - Provide data on the chemical analysis of tissue residues of organisms exposed to drilling fluids and selected metals in drilling fluids.

Project Title: Chemical Analysis for Energy Program (A-5*) - Provide organic analytical chemical support to the aquatic toxicity testing program at the EPA Gulf Breeze Laboratory.

3.3.1.1.2 Transport, Transformation and Fate of Drilling Muds in the Marine Environment. In order to establish permit conditions for discharges of drilling muds under the NPDES permit system, the movement and behavior of the material in the marine environment must be known in order to determine the zone of initial dilution and to

*Page number of project description in Appendix A.

TABLE 3-2

AGGREGATED SUMMARY OF MAIN RESEARCH AREAS OF THE DRILLING FLUID HAZARD ASSESSMENT PROGRAM

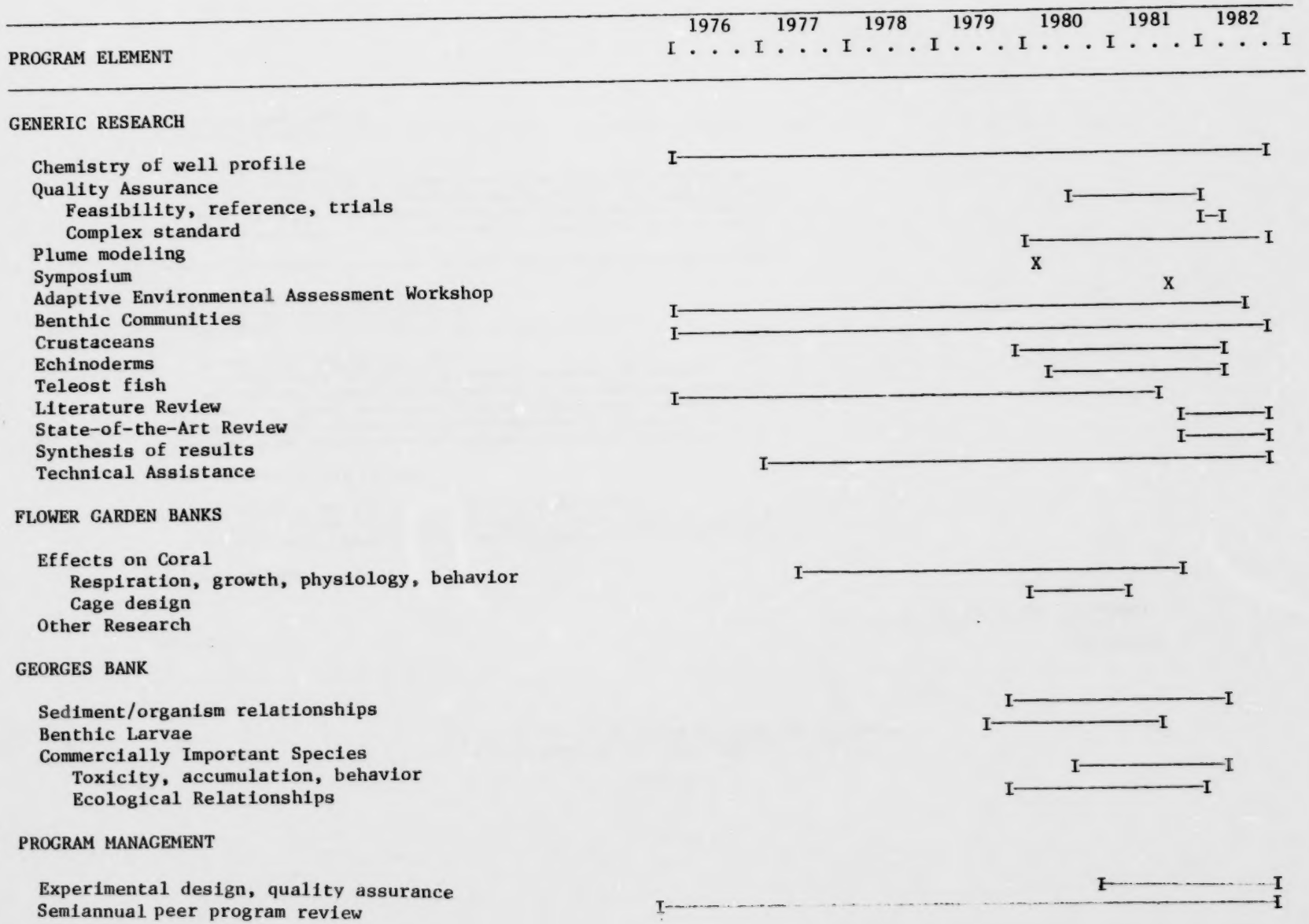

TABLE 3-3

PROJECT SCHEDULES FOR GENERIC STUDIES OF FATE
AND EFFECTS OF DRILLING FLUIDS IN THE MARINE ENVIRONMENT

PROJECTS	FISCAL YEAR 76	77	78	79	80	81	82	TOTAL FUNDING (Dollar in Thousands)
EXPOSURE ASSESSMENT								
Generic exposure assessment studies have involved the characterization of drilling muds and development of models for use in predicting drilling mud transport and dispersion in the marine environment.								
Characterization of Drilling Muds								
Because of the wide variation in drilling composition, analyses of used muds to which organisms have been exposed must be carried out in support of effects assessment research. Additionally, reference drilling muds of known chemical composition are needed for comparative toxicity testing and for use as chemical standards for quality assurance in analyzing used muds.								
Drilling mud reference standards for chemical analysis						X		90
Chemical analysis of drilling fluids						X		18
Chemical analysis for energy program						X		178
Transport, Transformation and Fate of Drilling Muds in the Marine Environment								
In order to establish permit conditions for discharge of drilling muds under the NPDES permit system, the movement and behavior of the material in the marine environment must be known in order to determine the zone of initial dilution and to estimate exposure of effected ecosystems and organisms to pollutants.								
Mixing zone definition for nonbuoyant discharges in support of section 403(c) of the Clean Water Act						X	X	111

TABLE 3-3 (Continued)

PROJECT SCHEDULES FOR GENERIC STUDIES OF FATE
AND EFFECTS OF DRILLING FLUIDS IN THE MARINE ENVIRONMENT

PROJECTS	FISCAL YEAR 76	77	78	79	80	81	82	TOTAL FUNDING (Dollar in Thousands)
EFFECTS ASSESSMENTS								
Since drilling muds and fluids contain components that are potentially toxic to marine organisms, knowledge of the effects of drilling muds after discharge on marine ecosystems and organisms must be obtained so that appropriate permit conditions can be established.								
Toxic, sublethal and latent effects of selected petroleum hydrocarbons and barium sulfate on marine organisms					X			383
Behavior assays for the effects of drilling muds on marine animals					X			34
Laboratory and field studies of used drilling fluids and fluid formulation components on benthic communities					X			500
Offshore pollutant effects program					X			622
Effect of drilling mud on marine organisms					X			85
Effects of drilling mud constituents on the sedimentary microflora and the base of marine benthic food web						X		145
Effects of soluble fractions of drilling fluids on larval development and behavior of Callinectes sapidus and Rhithropanopeus harrissii							X	63
Effects of drilling fluids on embryo development							X	106
Effects of barium sulfate on fertilization and early development							X	125
HAZARD ASSESSMENT								
A hazard assessment is the integration of knowledge of concentrations of drilling fluids that occur in the environment under specific conditions (exposure assessment) and the effects of these concentrations during the period of exposure on marine ecosystems and organisms (effects assessment)								
Completion of hazard assessment program							X	214

TABLE 3-3 (Concluded)

PROJECT SCHEDULES FOR GENERIC STUDIES OF FATE
AND EFFECTS OF DRILLING FLUIDS IN THE MARINE ENVIRONMENT

PROJECTS	FISCAL YEAR 76	77	78	79	80	81	82	TOTAL FUNDING (Dollar in Thousands)
SUPPORT TO THE RESEARCH EFFORTS								
Because the research efforts are multi-agency and multi-investigation efforts, communication and dissemination of information among the interested parties is needed to improve the coordination and effectiveness of efforts.								
Literature review of environmental effects of well-drilling, chemicals								
Effects of chemicals used in offshore oil and gas drilling operations on marine organisms					X			30
					X			486
								3,190 TOTAL

X=Project report or product.

estimate exposure of effected ecosystems and organisms to pollutants. A computer model is under development for use as a predictive tool in determining dilution and dispersion of a discharge from a proposed platform. Field studies underway on the Flower Garden Banks of actual discharge plumes will also contribute to a general understanding of plume behavior.

Project Title: Mixing Zone Definition for Nonbuoyant Discharges in Support of Section 403(c) of the Clean Water Act (A-6*) - Develop or revise mixing-zone calculation methods for industrial discharges, emphasizing ones containing fluids, emulsions, and suspensions heavier than marine water, or those which, in general, behave differently than municipal wastes for which mathematical models are available.

Related Project Title: Assessment of Exposure of the Texas Flower Garden to Pollutants Originating from Drilling Rigs - see section 3.3.2

Related Project Title: The Erodibility of Drilling Muds Deposited on the Sea Floor - see section 3.3.3

3.3.1.2 Effects Assessment

Since drilling muds and fluids contain components that are potentially toxic to marine organisms, knowledge of the effects of drilling muds after discharge on marine ecosystems and organisms must be obtained so that appropriate permit conditions can be established. Generic projects in this area are laboratory studies. Information gained in regional studies will also contribute to the overall understanding of the effects of drilling muds in the marine environment.

Project Title: Toxic, Sublethal and Latent Effects of Selected Petroleum Hydrocarbons and Barium Sulfate on Marine Organisms (A-7*) - Expose marine organisms, with emphasis on crustaceans, to components of drilling fluids. Determine acute and sublethal toxic effects and the potential for bioaccumulation of materials.

Project Title: Behavioral Assays for the Effects of Drilling Muds on Marine Animals (A-8*) - Develop a device capable of measuring the behavioral responses of the scallop to drilling fluids.

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*Page number of project description in Appendix A.

Project Title: Laboratory and Field Studies of Used Drilling Fluids and Fluid Formulation Components on Benthic Communities (A-9*) - Develop and apply methods for determining the effect of diesel oil on a marine offshore benthic community microcosm.

Project Title: Offshore Pollutant Effects Program** (A-10*) - Utilize offshore platform (Stage I) in the Gulf of Mexico 19 km south of Panama City, Florida owned and operated by the Naval Coastal Systems Laboratory for experiments on oceanic species for comparison with data obtained on estuarine species in other laboratory research projects.

Project Title: The Effect of Drilling Mud on Marine Organisms (A-11*) -Provide support for the operation of Stage I, and offshore research laboratory in the Gulf of Mexico near Panama City, Florida.

Project Title: Effects of Drilling Mud Constituents on the Sedimentary Microflora and the Base of the Marine Benthic Food Web (A-12*) - Determine effects that result from exposure of marine organisms.

Project Title: Effects of Soluble Fractions of Drilling Fluids on Larval Development and Behavior of Callinectes sapidus and Rhithropanopeus harrissii (A-13*) - The research includes measurements of drilling fluid effects on (a) long-term development of crab larvae, (b) short-term development of specific larval life stages, (c) swimming speed of larvae, and (d) positive or negative phototaxis of the larvae.

Project Title: Effects of Drilling Fluids on Embryo Development (A-14*) - The effects of drilling fluids on the developmental stages of the embryos of fish and echinoderms will be determined.

Project Title: Effects of Barium Sulfate on Fertilization and Early Development (A-15*) - The effects on sea urchin gametes and embryos will be assessed. The cellular events which are disturbed by barium sulfate will be characterized and the concentrations necessary to induce these perturbations will be determined.

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*Page number of project description in Appendix A.
**This project has been terminated because of storm damage to the platform.

Related Project Title: Development of Components of a Monitoring System - see section 3.3.2.

Related Project Title: New Methodologies for Measuring Energy-Related Consent Decree Toxic Compounds in the Marine Environment - see section 3.3.2.

3.3.1.3 Hazard Assessment

A hazard assessment is the integration of knowledge of concentrations of drilling fluids that occur in the environment under specific conditions (exposure assessment) and the effects of these concentrations during the period of exposure on marine ecosystems and organisms (effects assessment).

Project Title: Completion of Hazard Assessment Program (A-16*) - synthesize existing literature and conduct a limited amount of research on the effects of the fluids on selected marine organisms. Principle efforts will the directed toward completion of the five-year Drilling Fluid Hazard Assessment Program.

3.3.1.4 Support to the Research Efforts

Because the research on the effects of drilling fluids on the marine environment are multiagency and multi-investigator efforts, communication and dissemination of information among the interested parties is needed to improve the coordination and effectiveness of the efforts.

Project Title: Literature Review of Environmental Effects of Well-Drilling Chemicals (A-17*) - Prepare a review of available literature on the origins, fate and effects of chemicals discharged from oil and gas drilling operations into the marine environment.

Project Title: Symposium on the Effects of Chemicals Used in Offshore Oil and Gas Drilling Operations on Marine Organisms (A-18*) - Establish program committee for symposium, advertise meeting, select papers and session chairmen, hold meeting, publish proceedings.

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*Page number of project description in Appendix A.

3.3.2 Flower Garden Banks, Gulf of Mexico

Presently being investigated by several Federal agencies including EPA is the potential impact of proposed oil and gas drilling activities near the Flower Garden Banks in the Gulf of Mexico. This bank, located 120 nautical miles south of Cameron, Louisiana, contains the northernmost tropical coral reefs in the Gulf of Mexico. At issue is the potential harm that could result to the reef system from drilling muds discharged from platforms in the vicinity. Of chief concern is that turbidity and sedimentation of muds could adversely affect the coral.

At present the U.S. Department of the Interior requires that drilling should be limited to the edge of the bank and effluents from the platforms must be released to the naturally turbid layer of water near the bottom (nepheloid layer), where the material would probably remain in the lower density layer. Since coral growth is primarily restricted to surface waters, such a discharge practice should, in principle, protect the coral reef ecosystem. The certainty of this protection is only conjecture, however, since no research has been undertaken to verify its accuracy. Consequently, EPA has undertaken laboratory and field studies of the effect of drilling muds on reef organisms and field studies of discharge plume behavior. Some specific discharge-related questions being addressed by EPA research are as follows:

- Are drilling fluids or their components toxic to scleractinean corals in laboratory testing?
- Given the dispersion of discharged materials during drilling operations, will actual concentrations and exposure duration be produced that will adversely and significantly affect the coral reef ecosystem?
- Will discharge of fluids to the nepheloid layer protect corals from toxic drilling fluids if extensive oil and gas field development takes place?
- What is the expected and worst case of exposure to the reefs likely to be encountered during production drilling?
- Under actual surface discharge conditions, what minimal distance from the reef ecosystem is needed to mitigate against adverse exposure?

The research program on the Flower Garden Banks encompasses an exposure assessment and an effects assessment. In addition, biological monitoring methods necessary to carry out the research program

are under development. Several activities designed to support the overall research effort are also included, as is technical support to Region VI on an as-needed basis for permit review. The schedule and total funding for research projects is given in Table 3-4.

3.3.2.1 Exposure Assessment

Research has focused on dilution, dispersion, and fate of the plume of drilling fluid discharged from the platforms and on determining the extent of resuspension of drilling muds from the bottom.

Project Title: Assessment of Exposure of the Ecosystem of the Texas Flower Gardens to Pollutants Originating from Oil and Gas Drilling Rigs (A-20*) - Determine the transport, transformation and fate of materials discharged from drilling platforms. Field measurements of dispersion of particulate and dissolved components of fluid discharges will be used to develop predictive computer models for estimating dosage of ecosystems from wells near the Flower Garden Banks.

Related Project Title: The Erodibility of Drilling Muds Deposited on the Seafloor - see section 3.3.3.

3.3.2.2 Effects Assessment

The EPA research effort has focused on laboratory studies of the effect of drilling muds on reef organisms, principally corals. A field study of reef fish is also planned.

3.3.2.2.1 Coral Research. These efforts are aimed at determining what effects drilling fluids have on reef-building corals and what indicators of toxicity might be useful in field studies. Criteria for measuring coral stress include respiration nitrogen, lipids in corals and zooxanthellae, amino acids and rate of calcification, and neurochemcial and other biochemical characteristics.

Project Title: Offshore Laboratory Studies of the Impact of Used Drilling Fluids on Behavior of Corals Representative of the Flower Garden Banks (A-21*) - Expose corals to drilling fluids and determine the rate of sediment removal or polyp contraction.

*Page number of project description in Appendix A.

TABLE 3-4

PROJECT SCHEDULES FOR STUDIES OF FATE AND EFFECTS OF DRILLING FLUIDS ON THE FLOWER GARDEN BANKS, GULF OF MEXICO

PROJECTS	FISCAL YEAR 76	77	78	79	80	81	82	TOTAL FUNDING (Dollar in Thousands)
EXPOSURE ASSESSMENT								
Research has focused on dilution and fate of the plume of drilling fluids discharged from the platforms.								
Assessment of exposure of the ecosystem of the Texas Garden Banks to pollutants originating from oil and gas drilling rigs						X		790
EFFECTS ASSESSMENT								
The research effort has focused on laboratory studies, principally corals.								
Coral Research								
Offshore laboratory studies of the impact of used drilling fluids on behavior of corals representative of the Flower Garden Banks						X		500
Effects of drilling fluids and oil on coral occupying hard bank communities			X					64
Biochemical analyses on coral and other invertebrate metabolic activities and nutritional status with exposure to oil and gas drilling mud							X	92
Effects of drilling mud on corals: some biochemical and neurological aspects					X			117
Effects of offshore oil and gas drilling on reef building corals							X	188
Effects of oil drilling muds on the physiology and nutritional status of Texas Flower Garden Reef coral					X			134
Physical and chemical effects of drill mud on coral skeleton							X	76
Other Research								
Comparison of reef fish populations at the Flower Garden Banks and at oil and gas drilling platforms					X			660
Toxic and sublethal effects of waste drilling muds and certain chromium compounds in Crustaceans							X	261

TABLE 3-4 (Concluded)

PROJECT SCHEDULES FOR STUDIES OF FATE AND EFFECTS OF DRILLING FLUIDS ON THE FLOWER GARDEN BANKS, GULF OF MEXICO

PROJECTS	FISCAL YEAR 76	77	78	79	80	81	82	TOTAL FUNDING (Dollar in Thousands)
EFFECTS ASSESSMENT (Cont.)								
Biological Monitoring Methods								
Development of components of a monitoring system								
(I) Tethered cage						X		100
(II) Evaluation of devices and materials for seawater chemical sample collection - preconcentration and analysis						X		30
(III) Automatic sampler for trace organics in marine water						X		80
New methodologies for measuring energy-related consent decree toxic compounds in the marine environment						X		400
SUPPORT TO THE RESEARCH EFFORTS								
Because the research efforts in the Flower Garden Banks area is a multi-investigator and multi-agency effort, communication and dissemination of information among the interested parties is needed to improve coordination and effectiveness of these efforts.								
Adaptive environmental assessment workshops on drilling mud disposal							X	97
Identification of macroinfauna from experiments conducted at the U.S. Navy Platform "Stage I."						X		14
TECHNICAL ASSISTANCE TO EPA REGION VI								
EPA Region VI requires technical assistance in discharge permit matters								
Technical assistance to EPA Region VI					as needed			353
								3,956 TOTAL

X=Project report or product.

Project Title: Effects of Drilling Fluids and Oil on Corals Occupying Hard Bank Communities (A-22*) - Test the toxicity of a variety of drilling fluids to corals under laboratory and field conditions.

Project Title: Biochemical Analyses on Coral and Other Invertebrate Metabolic Activity and Nutritional Status with Exposure to Oil and Gas Drilling Mud (A-23*) - Develop and test biochemical measures of the effects of drilling muds on (1) the coral-zooxanthellae interaction using lipid analysis, (2) the nutritional status with the triglyceride, wax ester, phospholipid ratio, (3) the metabolic status of corals using the lipid analysis and gas chromatograph/mass spectrometry.

Project Title: Effects of Drilling Mud on Corals: Some Biochemical and Neurochemical Aspects (A-24*) - Study the effect of drilling mud treatment on some biochemical and neurochemical aspects of coral physiology. Specifically, these studies will include the evaluation of protein, nucleic acid, energy and catacholamine metabolism.

Project Title: Effects of Offshore Oil and Gas Drilling on Reef Building Corals (A-25*) - Expose corals to drilling fluids at the EPA-leased Navy platform in the Gulf of Mexico south of Panama City, Florida, and measure effects by time-lapse photography.

Project Title: Effects of Oil Drilling Muds on the Physiology and Nutritional Status of Texas Flower Garden Reef Coral (A-26*) - 1) Determine the effects of various concentrations of whole drilling mud on respiration, nitrogen excretion and calcification in a reef coral. 2) Determine the effects of various concentrations of whole drilling mud on the nutritional states of reef corals. 3) Send exposed corals to other investigators for complementary biochemical and histopathological investigations.

Project Title: Physical and Chemical Effects of Drill Mud on Coral Skeletons (A-27*) - measure the physical and chemical record in coral skeletons using density of minerals deposited in the skeleton during periods of growth.

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*Page number of project description in Appendix A.

3.3.2.2.2 Other Research. The effect of drilling fluids on reef fish populations and crustaceans is being determined.

Project Title: Comparison of Reef Fish Populations at the Flower Garden Banks and at Oil and Gas Drilling Platforms (A-28*) - Assess the biological characteristics of natural reef fish populations and compare them with those of reef fish populations associated with oil and gas platforms in the northwestern Gulf of Mexico.

Project Title: Toxic and Sublethal Effects of Waste Drilling Muds and Certain Chromium Compounds in Crustaceans (A-29*) - Laboratory experiments will be used to investigate the effects of drilling muds and their components on crustaceans.

3.3.2.2.3 Biological Monitoring Methods. Validation of laboratory experiments in the field require methods for exposing organisms to chemical and physical conditions in the drilling fluid plume. Also needed are methods to monitor conditions in the plume.

Project Title: Developments of Components of a Monitoring System - (I) Tethered Cage (A-30*) - The cage would be capable of maintaining its position in the thermocline and would be fitted with special devices for remotely monitoring the health status of the caged animals.

Project Title: Development of Components of a Monitoring System - (II) Evaluation of Devices and Materials for Seawater Chemical Sample Collection, Preconcentration, and Analysis (A-31*) - The program has three objectives: Determination of performance and contamination characteristics of existing monitoring systems, specifically those that will be used in Texas Flower Gardens research; evaluation of preconcentration materials; and, development of laboratory analytical techniques.

Project Title: Development of Components of a Monitoring System - (III) Automated Sampler for Trace Organics in Marine Waters (A-32*) - The Sampler should be able to collect particulate and dissolved materials samples and preserve both in uncontaminated condition until removal for subsequent analysis. The sampler should be programmable in terms of sampling intervals and freqencies and the collected samples should be ready for analysis without significant additional handling or processing.

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*Page number of project description in Appendix A.

Project Title: New Methodologies for Measuring Energy-Related Consent Decree Toxic Compounds in the Marine Environment (A-33*) - This project has three objectives: (1) validated methods for separating trace organic marine pollutants into major chemical classes and removal of natural marine organics that interfere with pollutant analysis; (2) validated techniques for final detection, identification and measurement of individual trace organic pollutants; and (3) identification of potentially hazardous organic pollutants from marine water samples from the Texas Flower Gardens as well as from areas near various ocean outfalls.

3.3.2.3 Support to the Research Efforts

Because the research efforts in the Flower Garden Banks area is a multi-investigator and multi-agency effort, communication and dissemination of information among the interested parties is needed to improve the coordination and effectiveness of these efforts. The EPA program includes an adaptive environmental assessment workshop and taxonomic identification in support of research activities.

Project Title: Adaptive Environmental Assessment Workshop on Drilling Mud Disposal (A-34*) - A scoping meeting with EPA personnel will be held to identify the specific problem to be addressed by a hypothetical model. Staff assistance and guidance will be provided by DOI in conducting an EPA-sponsored adaptive environmental assessment workshop.

Project Title: Identification of Macroinfauna from Experiments Conducted at the U.S. Navy Platform "Stage I" (A-35*) - Identify benthic organisms in support of "Stage I" research on the effects of drilling fluids on marine organisms.

3.3.2.4 Technical Assistance to EPA Region VI

EPA Region VI requires technical assistance in discharge permit matters. This assistance will be provided as needed for permit review.

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*Page number of project description in Appendix A.

Project Title: Technical Assistance to EPA Region VI (A-36*) - The EPA Gulf Breeze Environmental Research Laboratory will provide technical assistance to EPA Region VI on NPDES permitting of discharges from offshore oil and gas drilling activities.

3.3.3 Georges Bank, Gulf of Maine

Georges Bank is a shallow submarine bank located off Cape Cod along the southern boundary of the Gulf of Maine. Leasing for exploratory drilling in this area has taken place. Exploratory drilling will begin in the summer of 1981.

The fishery of the Georges Bank is among the most productive in the world. Commercially important species include haddock, cod, pollack, whiting, lake cusk, American dab, yellowtail flounder, grey sole, sea herring, flounder, and lobster. The ecological processes that support the rich fishery are not clearly understood. However, productivity is related to an annual cycle of succession of benthic organisms. Winter storms scour the bottom, leaving many areas barren of biota. Springtime microbial blooms reduce erosion of sediments through a kind of gluing process. Meiofauna and macrofauna then dramatically increase their biomass in sediments. This productive habitat supports a diverse community of groundfish and crustaceans.

At issue on the Georges Bank is the potential harm that could occur to the commercial fishery from drilling activities, particularly from the discharge of drilling muds. To address this issue, EPA research has focused on the effects of drilling fluid on the following:

- Laboratory studies on the effect of commercially important species
- Benthic communities and organisms
- Sediment-animal relationships
- Sediment erodibility.

Exposure assessments and effects assessment have been undertaken as part of the Georges Bank research. Project schedules and total funding are given in Table 3-5.

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*Page number of project description in Appendix A.

TABLE 3-5

PROJECT SCHEDULES FOR STUDIES OF FATE
AND EFFECTS OF DRILLING FLUIDS ON GEORGES BANK, GULF OF MAINE

PROJECTS	FISCAL YEAR 76	77	78	79	80	81	82	TOTAL FUNDING (Dollar in Thousands)
EXPOSURE ASSESSMENT								
Because no drilling has taken place, no field studies related to discharge plume behavior have been planned.								
The erodibility of drilling muds deposited on the sea floor							X	154
EFFECTS ASSESSMENT								
Research is under way on toxicity to adults, behavioral effects, and larval development utilizing several important species of the Georges Bank area.								
Toxicity and Other Effects								
Effects of drilling mud on adult American lobster					X	X		132
Drilling fluid effects to developmental stages of the American Lobster						X		30
Feeding, reproduction and habitat selection of lobster Homarus Americanus- effects of drilling mud in laboratory and field situations						X		134
The effects of drilling muds on the behavior and benthic ecology of three gadid species							X	118
A study of the impact of discharged drilling fluid on the organisms of Georges Bank[a]					X		X	405
Effects on Benthic Communities and Animal-Sediment Relationships								
The impact of drilling muds on standing stocks and metabolic activities of sediment bacteria							X	60
Benthic communities and drilling fluid effects on the conditions for larval settlement on the Georges Bank						X		81
								1,114 TOTAL

[a]Final year will entail work on marine and estuarine organisms from areas other than the Georges Bank.
X=Project report or product.

Recent settlement of two law suits regarding research on the Georges Bank (Commonwealth of Massachusetts vs. Andrus; Conservation Law Foundation of New England vs. Andrus) has established the Department of the Interior as the agency responsible for conducting studies. EPA will provide recommendations for research through its participation on the Biological Task Force that has been established to advise the Department of the Interior. The EPA will not be funding drilling mud research specific to Georges Bank in FY82.

3.3.3.1 Exposure Assessment

Because no drilling has taken place, no field studies related to discharge plume behavior have been planned as part of the EPA Georges Bank research effort. A laboratory study of drilling-fluid-affected sediment erodibility will be carried out because of the importance of sediment dynamics in determining ecosystem structure and function. Transport models developed as part of the generic studies could be applied to the Georges Bank environment. Plume studies carried out in the Flower Garden Bank area of the Gulf of Mexico will also provide knowledge that could be applied to the Georges Bank situation.

Project Title: The Erodibility of Drilling Muds Deposited on the Sea Floor (A-38*) - Laboratory flume studies and field observations will be used to determine drilling mud stability once deposited on the bottom.

Related Project Title: Mixing Zone Definitions for Nonbuoyant Discharges in Support of Section 403(c) of the Clean Water Act - section 3.3.1.

Related Project Title: Assessment of Exposure of the Ecosystem of the Texas Flower Garden Bank to Pollutants Originating from Oil and Gas Drilling Rigs - section 3.3.2.

3.3.3.2 Effects Assessment

Research on effects of drilling fluids consists of the following:

- Laboratory studies of toxicity and other effects on important species of the area
- Effects on benthic communities and animal-sediment relationships

*Page number of project description in Appendix A.

3.3.3.2.1 Toxicity and Other Effects. Research is under way on toxicity to adults, behavioral effects, and larval development utilizing several important species of the Georges Bank area.

Project Title: Effects of Drilling Mud on Adult American Lobsters (A-39*) - The effects of drilling muds on feeding, molting, mating, predator escape, shelter behavior, and substrate selection will be determined by controlled laboratory experiments, in seminatural environments, and by observations in the field.

Project Title: Drilling Fluid Effects to Developmental Stages of the American Lobster (A-40*) - The effects of used, whole drilling fluids on larval and postlarval stages of the lobster will be assessed.

Project Title: Feeding, Reproduction and Habitat Selection of Lobster, Homarus Americanus - Effects of Drilling Mud in Laboratory and Field Situations (A-41*) - Field, laboratory and neurophysiological studies of the behavior of larval and young lobsters and the relation to exposure to drilling fluids will be carried out.

Project Title: The Effects of Drilling Muds on the Behavior and Benthic Ecology of Three Gadid Species (A-42*) - The effect of muds on juveniles will be determined.

Project Title: A study of the Impact of Discharged Drilling Fluid on the Organisms of the Georges Bank (A-43*) - Toxicity tests will be undertaken.

3.4.3.2.2 Effects on Benthic Communities and Animal-Sediment Relationships. Because of the importance of the benthic community to the structure and function of the Georges Bank ecosystem, research on the effects of drilling fluids on the benthic community and animal-sediment relationships is an important part of the EPA program.

Project Title: The Impact of Drilling Muds on Standing Stocks and Metabolic Activities of Sediment Bacteria (A-44*) - This project will examine the impact of drilling mud on bacteria populations. Bacterial populations from sediment samples will be counted and their growth rates determined.

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*Page number of project description in Appendix A.

Project Title: Benthic Communities and Drilling Fluid Effects on the Conditions for Larval Settlement on the Georges Bank (A-45*) - Traps will be used for in situ experiments on the effects of drilling fluids on larval settlement.

*Page number of project description in Appendix A.

4.0 RESEARCH RESULTS TO DATE

4.1 INTRODUCTION

Most of the work initiated as part of the Drilling Fluids Hazard Assessment Program is now yielding preliminary results. Additionally, results of studies undertaken by other Federal agencies and the oil industry are becoming available. Corroboration of these initial results must await completion of work in progress and additional scrutiny and verification of the results by the scientific community.

Given below is a brief overview of the results to date of EPA and some other research. The results discussed are divided into exposure assessment and effects assessment. Exposure assessments have been grouped into the following categories.

- Field studies of discharge plume dispersion
- Models of plume dispersion
- Sedimentation and monitoring studies

Effect assessment studies have been grouped into the following categories.

- Pentachlorophenol tests
- Short-term toxicity tests
- Long-term toxicity tests
- Bioaccumulation studies
- Effects on benthic communities
- Effects on corals

4.2 EXPOSURE ASSESSMENT

Available research results related to exposure assessment mostly deal with field studies of dispersion and fate of drilling fluid discharges from exploratory drilling platforms. These studies have been carried out by the oil industry. Studies sponsored by EPA are in an early stage.

4.2.1 Field Studies of Discharge Plume Dispersion

At present, five studies of discharge plume dispersion of drilling fluids from offshore platforms carried out by oil companies have been published. Four of these studies have involved open ocean situation and one a tidal embayment:

- Mid-Atlantic Ocean (Baltimore Canyon)
- Gulf of Mexico (two studies)
- Lower Cook Inlet, Alaska
- Southern California Shelf (Tanner Bank)

The research design and documentation is considered adequate on only four of the five studies (Ayers et al., 1980a, 1980b; Ray and Meek, 1980; Houghton et al., 1980). One of the Gulf of Mexico studies (Ray and Shinn, 1975) is considered flawed, so that the validity of the results cannot be established with any degree of confidence. These studies have been critiqued by Petrazzuolo (1981).

Several general observations have resulted from the four studies for which documentation of methods and findings is considered adequate.

- Two plumes form when the material leaves the discharge pipe. A lower heavier plume contained the bulk of the solids and descended rapidly. The upper plume, containing five to seven percent of the suspended solids, remained in the water column for a much longer period and drifted away from the source with the prevailing current.
- Dilution factors of several hundred to several thousand were reached within a few meters of the discharge. Wave-induced mixing within the submerged portion of the discharge pipe may contribute significantly to this dilution.
- Background concentrations of suspended solids in the upper long-lasting plume were achieved within 500 m to 1000 m of the source. These results were variable depending on a number of conditions, such as sea state and discharge rate.
- Dilution of the discharge is enhanced by the turbulent wake created by the drilling rig. This result was suggested by modeling and in-situ measurements at the well in Lower Cook Inlet, Alaska (Houghton et al., 1981). Additional observations are necessary to confirm this, however.

4.2.2 Models of Plume Dispersion

The modeling effort by EPA related to discharges is just beginning. Several modeling efforts by the oil industry have been undertaken. These studies have been critiqued by Petrazzuolo (1981). The results of plume dispersion measured for a well in the Lower Cook Inlet were fitted to several types of plume dispersion models.

- Discharge of a jet in deep water
- Plume would follow the behavior of wake dispersion and growth
- Thermal plume model

Although these models are designed to simulate continuous releases, the best fit to the field data was achieved for bulk discharges. No real satisfactory fit to continuous discharge data was achieved with any of the models.

A computer model of drilling fluid plume dispersion has been developed by Brandsma et al. (1980). The model is an evolution of earlier models for dredged material discharges. The discharge is assumed to originate as a jet. There are three phases of plume dispersion:

- Jet phase - entrainment of ambient fluid and reorientation of the plume to the ambient current
- Dynamic collapse - occurring either when the plume reaches the bottom or arrives at the level of neutral buoyancy, at which time horizontal spreading dominates.
- Passive diffusion - commences when transport and spreading of the plume is determined more by ambient currents and currents than by any dynamic character of its own.

The model results were compared to field data of a fluid release from a well in the Gulf of Mexico (Ayers et al., 1980b). The model results and field data agreed fairly well with respect to vertical profiles at various distances from the discharge pipe. The tendency was for the calculated profile to be located at somewhat shallower depths in the near field and somewhat deeper depths in the far field.

4.2.3 Sedimentation and Monitoring Studies

The results of eight studies of sedimentation from drilling operations have been reviewed by Petrazzuolo (1981). All of the studies suffer from some problems with research design, methodology,

or documentation that reduce confidence in the results or make it more difficult to draw conclusions. Several of the studies have such serious flaws that they are of little utility in determining the environmental fate of drilling fluids and cuttings.

Ayers et al. (1980b) have reported on sedimentation of material from a 275 bbl/hr. and a 1000 bbl/hr. discharge from a well in the Gulf of Mexico. Sediment traps were placed from 30m to 200m downcurrent of the discharge. Solids in the lower plume (see Section 4.2.1) were deposited on the bottom within 10m of the discharge, so no material from this plume was collected in the sediment traps. Movement of the discharge pipe during the 1000 bbl/hr. release introduced uncertainty into the results, since the pipe was securely clamped in place during the 275 bbl/hr. test.

Material collected in the traps was one to two orders of magnitude greater at 100m to 200m during the 1000 bbl/hr. release than during the 275 bbl/hr. release. The transport time for barium was increased relative to suspended solids. Thus, the barium to suspended solids ratio in sedimented material is less than half the ratio in the discharged material, suggesting that the barium content of the material remaining in the water column is relatively increased.

Sediment barium levels as a function of distance from the platform before and after drilling have been determined at three wells in the Gulf of Mexico (reviewed in Petrazzuolo, 1980). The post-drilling levels in these three studies exhibited a consistent pattern as a function of distance from the source. When considered as a whole, the post-drilling sediment barium content appeared to follow generally the inverse square root of the distance. The data did not conclusively support a square root dispersion model, but indicate that further study of this relationships may prove fruitful.

4.3 EFFECTS ASSESSMENT

Many studies of the effect of drilling fluids on marine organisms have been undertaken since the inception of the EPA Drilling Fluids Hazard Assessment Program. Some early results are available from EPA sponsored studies. Other studies have been funded by the oil industry. Many results have been published in the proceedings of a recent symposium (Research on Environmental Fate and Effects of Drilling Fluids and Cuttings, January 1980).

4.3.1 Pentachlorophenol Tests

Early in the EPA research Program the potential toxicity of the biocide pentachlorophenol, which was used in some drilling muds, was

examined. A symposium was sponsored by EPA at which the toxic effect and distribution of this compound was discussed. Subsequently its use was banned by the U.S. Geological Survey.

4.3.2 Short-Term Toxicity Tests

Results of 96-hour toxicity tests sponsored by EPA using barite and used drilling muds have been reported by Conklin et al. (1980). The toxicity of 18 different samples of muds from a well in Mobile Bay, Alabama, was tested (see Section 3.2.3). None of the muds was toxic to intermolt grass shrimp Palaemonetes pugio at mud concentrations of 10 and 100 ppm. But at a concentration of 1000 ppm, six of these muds caused 30 to 60 percent mortality of intermolt grass shrimp, while one mud caused 100 percent mortality. Toxicity tests with molting grass shrimp yielded LC 50 values of 363 to 739 ppm for 5 of the mud samples.

The toxicity of four types of used chrome lignosulfonate drilling mud-seawater mixtures to different life stages of the opossum shrimp Mysidopsis almyra Bowman was evaluated by Carr et al., (1980). The mud-seawater mixtures were also prepared with a natural reference sediment obtained from San Antonio Bay, Texas, in order to determine the deleterious effects of exposure to naturally occurring fine clay particulates as opposed to those of drilling mud origin.

No appreciable mortality was observed for one-day old juveniles exposed to reference sediment-seawater mixtures while similar exposures to drilling mud preparations were acutely toxic. Drilling mud particulates were harmful to juvenile mysids. However, the majority of the toxicity of the used drilling mud resided in the water-soluble and fine particulate fractions of the mud. The 96 hour LC50 values for one-day old mysids exposed to the mud aqueous fraction (MAF) of the drilling mud which was replaced daily was 27 percent, corresponding to 27,000 ppm mud added to water. The most sensitive stage in the life history of M. almyra to drilling mud exposure was at the first juvenile molt, which normally occurs between 24 and 48 hours after release.

The weight-specific respiration rate of mysids exposed to a sublethal mud aqueous fraction (MAF) for 24 hours was significantly greater than that of controls. After seven days of exposure to sublethal MAFs the weight-specific respiration rates were not significantly different. A dose-dependent retardation in growth was observed, however, for one-, three-, and six-day old mysids exposed to MAFs. An increased feeding activity was observed for first and second day juveniles exposed to different MAF concentrations. The authors believe that the results indicate that drilling mud exposure

reduced biomass production and net growth efficiency of mysids at sublethal concentrations in the range of 15 to 30 percent MAF. Other metabolic processes concerned with energy transfer such as gamete production could be affected by similar exposures.

Gerber et. al (1980) have used 96-hour static bioassays to determine the relative toxicity of five used drilling fluids collected from offshore drilling rigs, and various components of these fluids, to cold water marine animals. Organisms which survived these tests were then assayed for levels of cellular enzyme activities, or changes in the rates of respiration, excretion, and ingestion were determined, as indications of sublethal stress. The drilling fluids to be tested were used in the following forms: whole mud, aqueous fraction, and suspended whole mud.

With few exceptions the adult animals when exposed for 96 hours to the various fractions of the drilling fluids exhibited little mortality. Whole muds were slightly more toxic than the mud aqueous fractions to most organisms but especially to deposit feeding organisms, and larvae were more sensitive than adults. Most organisms exposed to various concentrations of the mud fractions had cellular enzyme activities different from the controls, and differences in enzyme activities rates were apparent for the different drilling fluids or components. It was concluded from the 96-hour bioassays that these drilling muds were most toxic to larval marine organisms, and though much less toxic to adults, sublethal stress was evident.

The acute toxicity to several species of marine animals of four used offshore drilling muds was investigated by Neff et al., (1980). The four drilling muds included a spud mud (density, 9.2 lb/gal), a seawater chrome lignosulfonate mud density, 13.4 lb/gal). Two mud-seawater preparations designated the mud aqueous fraction (MAF) and suspended particulate phase (SPP) were used in bioassays. The SPP was similar to the MAF except that it contained a higher concentration of suspended particulates initially (900 vs 600 mg/l). The stock 100 percent MAF and SPP preparations represented the water-soluble plus fine particulate fractions of 100,000 ppm (10 percent v/v) mud in water.

All four drilling muds had a low acute toxicity to all species tested. The used spud mud was completely non-toxic. The three other used drilling muds varied in their relative toxicity to different species and life stages of marine animals. In most cases, the mid-weight lignosulfonate drilling mud was more toxic than the seawater chrome lignosulfonate drilling mud and the high weight lignosulfonate drilling mud.

The 96-hour median lethal concentration (96 h LC 50) of the MAF of the three used chrome lignosulfonate drillings muds varied from 12.8 percent MAF for the first day postlarvae of the opossum shrimp Mysidopsis almyra to greater than 100 percent MAF for adult grass shrimp Palaomonetes pugio and the polychaete worm Ophryotrocha labronica. Ninety-six hour LC 50 values for two species of bivalve molluscs exposed to the SPP ranged from 20-74 percent SPP. Comparisons of the acute toxicity of the two mud preparations indicated that much of the toxicity of drilling mud resided in the water-soluble fraction. Based on results of these bioassays and dispersion-dilution models of drilling muds discharged from offshore platforms, it was concluded that discharge of used drilling muds like those studied would have little or no acute lethal effect on marine animals in the vicinity of the platform.

Laboratory bioassays were conducted in a portable laboratory located on a semisubmersible drilling vessel during the drilling of the Lower Cook Inlet, Alaska Continental Offshore Stratigraphic Test (C.O.S.T.) well (Houghton et al., 1980). The tolerances of seven indigenous organisms with a wide range of ecological requirements were tested using static, acute, 48- and 96-hour bioassays. Test solutions were prepared from drilling fluids taken directly from the mud pits and mixed with ambient sea water. Toxicity of drilling fluids was generally low with 96-hour LC 50 values ranging from 3,000 ppm (0.3 percent by volume of drill fluids to sea water) for pink salmon to greater than 100,000 ppm (10 percent) for shrimp. LC 50 values were lower in tests in which the solutions were continuously mixed than in tests in which solutions were well mixed initially and then allowed to settle during the remainder of the test.

Acute toxicity experiments were conducted in the field on key Arctic marine species using various types of freshwater drilling fluids obtained from drilling rigs operating in the vicinity of Prudhoe Bay, Alaska (Tornberg et al., 1980). The results of static bioassays indicated that test organisms varied widely in their responses to exposure to drilling effluents. Ninety-six hour LC 50 values ranged from 4 percent to greater than 70 percent (drilling fluid volume to seawater volume) for drilling fluids tested. Fish were among the most sensitive organisms tested and invertebrates included both sensitive and relatively resistant species. The resistant species were primarily sedentary, while more sensitive species generally had the capability of migrating into and away from a drilling fluid disposal site.

Variations in drilling fluid characteristics appeared to produce variations in toxicities approaching those among different species. Drilling fluids characterized as CMC/Gel/Resinex (used near the bottom of a well) were more toxic to selected marine organisms than were

XC-Polymer drilling fluids (used at mid-well depths), which, in turn, were more toxic than CMG/Gel drilling fluids (used in the upper depths of the well).

4.3.3 Long-Term Toxicity Tests

Results are available on only a few studies involving long-term exposures of organisms to drilling fluids. Organisms on which tests have been conducted include grass shrimp, a mysid, the American oyster, and a polychaete worm.

A flow-through system was employed by Conklin et al. (1980) to assess toxicity of drilling mud during the molt cycle of the grass shrimp (Palaemonetes) and the life cycle of Mysidopsis bahia. The muds used were from a well in Mobile Bay, Alabama. The oil company has since claimed that these muds were atypical. Mysids were more sensitive than grass shrimp to drilling mud exposure. In life cycle tests with mysids, the LC 50 for one of the muds was 50 ppm. The LC 50 values obtained with tests involving molting grass shrimp and mysids are several orders of magnitudes lower than previously reported LC 50 values for fishes.

A long-term (100 days) multispecies toxicity test was conducted by Rubenstein et al. (1980) to elucidate biological effects of drilling fluids on representative estuarine organisms and developing benthic communities. Drilling muds, collected weekly from an active drilling site, were introduced into 10 gallon aquaria containing clean silica sand (10 cm deep) and flowing seawater (380 l/min). Three nominal concentrations of drilling fluids (10 ppm, 30 ppm and 1000 ppm) were continuously infused into test aquaria.

Organisms selected for study were: the mysid shrimp, Mysidopsis bahia, a water column crustacean, the oyster, Crassostrea virginica, an epibenthic mollusk, and a deposit-feeding polychaete, Arenicola cristata (commonly called the lugworm). Test criteria were developed to identify effects of drilling fluids on: (1) survival of mysids; (2) shell deposition and bioaccumulation of drilling fluid constituents by oysters; 3) survival of lugworms; and 4) recolonization of test substracts by macrofaunal organisms that settled in aquaria from planktonic larvae within the 100-day test period.

Results indicate that the drilling fluids tested were moderately toxic to mysids at 30 and 100 ppm. Oyster growth was also significantly inhibited at these concentrations. Lugworm survival in all three concentrations was significantly reduced. Finally, exclusion of colonizing polychaetes was observed in aquaria containing 100 ppm drilling fluids. These tests, however, used a drilling mud from a well in Mobile Bay, Alabama, that is claimed to be atypical in composition for discharge into marine waters.

4.3.4 Bioaccumulation Studies

Several studies are available on the potential for bioaccumulation of drilling fluid components by marine organisms. Organisms studied include the grass shrimp and three species of molluscs.

When exposed to media containing barite or used drilling mud, the grass shrimp Palaemonetes pugio ingested the settled barite and drilling mud particles (Conklin et al., 1980). Ultrastructural studies on the midgut of shrimp exposed for a 30-day period to 100 ppm or 500 ppm barite-containing media and living on the resulting substrate showed that prolonged ingestion of barite causes marked perturbations in the posterior midgut epithelium.

Barium has been shown to accumulate in hard and soft tissues of grass shrimp (Palaemonetes pugio) (Brannon and Rao, 1979). The relative mineral composition of the cast shells of barite-exposed shrimp was markedly different from that of the control shrimp. Whether this accumulation had any harmful effects was not determined.

Houghton and Beyer (1980) have reported increases in total metals concentrations in amphipods when exposed to various drilling fluid concentrations. Sources of metal accumulation may include both water soluble metals and metals found in particulates.

The bioavailability of chromium, lead, and zinc from four used drilling muds to the marsh clam Rangia cuneata and the Pacific oyster Crassostrea gigas was investigated by McCulloch et al. (1980). The four used drilling muds included a spud mud, a seawater chrome lignosulfonate mud, a mid-weight lignosulfonate mud and a high weight lignosulfonate mud.

Clams (R. cuneata) accumulated significant amounts of chromium when exposed for four days to a substrate containing a layer of chrome lignosulfonate mud. However, most of the chromium was released within 24 hours when the clams were returned to clean seawater, indicating that much of the chromium accumulated was in the form of unassimilated mud components in the digestive tract or on the gills. When the clams were exposed to an aqueous fraction (water soluble fraction) of the mud for 16 days, they accumulated a mean of 19 parts per million chromium. When returned to clean seawater they released approximately half the chromium in 24 hours. The clams accumulated small amounts of chromium and lead from the mud aqueous fraction of a mid-weight lignosulfonate mud. Less than half the accumulated chromium and lead was released in four days when the clams were returned to clean seawater.

When spat of the oyster C. gigas were exposed to several concentrations of the suspended particulate phase of spud mud and mid-weight lignosulfonate mud for four days, they accumulated significant amounts of chromium from the mid-weight but not from the spud mud. When exposed to the mud aqueous fraction of three drilling muds for up to two weeks, the oyster spat showed little or no net accumulation of chromium, lead or zinc. The authors concluded from these experiments that heavy metals from typical used drilling muds had a limited bioavailability to marine bivalve molluscs during short term exposure. Chromium was more bioavailable than lead or zinc.

The uptake of chromium by Mytilus edulis from several test solutions was studied at pH 7.8 by Page et al. (1980). The solutions were (1) an aqueous extract of a medium density lignosulfonate mud, (2) a solution of ferrochrome lignosulfonate at two different concentrations, (3) a solution of Cr^{3+}. All solutions were of approximately equal concentration in total chromium except for one test solution of ferrochrome lignosulfonate at a 10 fold excess concentration compared with the others. The mussels gained the most chromium from the Cr^{3+} solution followed by the ferrochrome lignosulfonate solutions and the least from the used drilling mud extract. The authors felt that these results showed that the form of chromium available had a major effect on its uptake by organisms and should be taken into account in assessing potentially harmful effects of discharges of used drilling muds at sea.

4.3.5 Effects on Benthic Communities

Because solids from the discharged drilling fluids settle to the bottom in the vicinity of the drilling platform, benthic communities could be affected. Initial results from several EPA-funded studies are available.

Drilling fluids and their components have been shown to alter the composition of estuarine benthic communities at microbial, meiofauna and megafunal levels. White (manuscript in preparation), using new methodologies developed by EPA funding, has shown that some components of drilling fluids alter the microbial community structure of marine sediments at concentrations in the parts per billiom range. Biochemical analysis of these sediments showed total benthic biomass was not affected by drilling fluid components. However, two drilling mud additives were shown to selectively inhibit portions of the benthic microbial community. Surflo (800 ppb) and Dowicide (100 ppb) increased the biomass of bacterial containing the anaerobic pathway of fatty acid synthesis. Microeucaryotes were inhibited by Surflo. Surflo and Dowicide were shown to decrease the ratio of benthic algae to total microeucaryotes while Aldicide increased this ratio.

Tagatz et al. (1980) has shown that drilling fluids and their components affect the community structure of the meiofaunal populations colonizing estuarine sediments in laboratory microcosms. Aquaria contained sand and were continuously supplied with unfiltered seawater. Whole drilling mud, barite, a paraformaldehyde-type biocide (Aldacide®), and three chlorophenol-type biocides (pentachlorophenol, Dowicide® G-ST, and Surflo® B-33) were tested. Tests with whole drilling mud and barite were designed to determine their impact as a cover (2 or 5 mm) over the substratum and when mixed with clean sand (ratios of 1:10 sand and higher). Annelids were most sensitive to drilling mud and barite and significantly fewer numbers of organisms occurred in all contaminated aquaria than in control aquaria. For all phyla, the average number of species per aquarium was significantly less in treatments with a cover of mud or barite than in the controls. Mollusks were particularly affected by the chlorophenol-type biocides and significantly fewer occurred at concentrations (active ingredient in water) of 7 ug pentachlorophenol/l, 18 ug Dowicide G/l, and 10 ug Surflo B-33/l. Numbers of individuals and species of annelids per experimental aquarium containing 76 ug pentachlorophenol/l, 183 ug Dowicide G/l, and 205 ug Surflo B-33/l were also significantly less than in control aquaria. Numbers of animals and species did not significantly decrease in the presence of Aldacide at nominal concentrations (active ingredient) as high as 273 ug/l.

Similar studies are being conducted near Georges Bank. Gilbert (manuscript in preparation) conducted *in situ* studies of the effects of drilling fluids on meiofaunal succession of Waquoit Bay sediments. Drilling fluids either mixed into or layered on sediment suppressed the biomas of the recolonizing community and altered the meiofaunal community structure. Contaminated sediments reduced the total number of individuals by 52 to 38 percent (when corrected for mobile species). *Capitella capitata*, an indicator of marine pollution, was more numerous in the drilling mud treatments than in controls.

4.3.6 Effects on Corals

EPA has funded a number of studies on the effects of drilling muds on corals as part of the research effort related to the Flower Garden Banks. Some initial results of these studies are available.

Seven species of coral, *Dichocoenia stokesli*, *Nontastrea annularis*, *Agarcia agaricites*, *Acropora cervicornis*, *Porites furcata*, *P. astreoids*, and *P. divaricata*, were experimentally exposed to each of these concentrations (100, 316, 1000 ppm) of drilling mud (obtained from an off shore oil well in the Gulf of Mexico), and control sea water for 96 hours to observe behavioral response (Thompson and Bright, 1980). Experiments were conducted at Carysfort Reef, Florida

Keys, using closed aquaria located in three meters of water. Polyp behavior was determined with serial closeup photography, which allowed counting of retracted, partially retracted, and non-retracted polyps in each colony. Response to drilling mud concentrations was measured as percent of polyps retracted. Montastrea annularis, Agaricia agaricites, and Acropora cervicornis were killed by exposure to 1,000 ppm mud. A. cervicornis colonies survived this concentration in a replicate experiment. All corals except Dichocoenia stokesii and Porites divaricata showed significant polyp retraction during exposure to 100 ppm mud concentration, which 316 ppm mud was the minimum concentration which induced significant polyp retraction in Porites divaricata. Polyps of Dichocoenia stokesii did not detectably react to any of the three concentrations.

Possible effects of drilling mud on the growth of Montastraea annularis were evaluated in the following separate studies (Hudson and Robbin, 1980): (1) short-term recovery and subsequent growth of this species exposed to drilling mud on a Florida reef, and (2) long-term growth record of these corals from East Flower Garden Bank, Gulf of Mexico, an area of possible exposure to drilling mud from nearby exploratory drilling operations that took place during 1974 and 1977.

In the short-term experiment, eight M. annularis head corals were heavily dosed with drilling mud and left with 10 untreated control corals on the reef for six months to recover and grow. All corals were then collected and analyzed using X-radiography to determine post-treatment growth rates. Barium and chromium levels incorporated in the coral skeleton before and after the experiment were determined by emission spectroscopy. Barium levels ranged from 11 ppm (background) in pretreatment skeletal areas to as high as 1,200 ppm in skeletal areas deposited during and after treatment. Chromium concentrations were at or below background levels in all samples. In the second study, cores taken by divers from large M. annularis heads at East Flower Garden Bank were analyzed in the same manner as those in the first experiment. Annual growth rates averaged 8.9 mm over a 50 year period (1907-1957). In 1957 average yearly growth declined sharply and has remained 1.7 mm below previous long-term growth averages. Concentrations of barium and chromium were at or below background levels in skeletal material from both predrilling growth periods and growth periods during drilling operations.

Madracis decactis corals were exposed for 17 days in laboratory aquaria to suspensions of 100 ppm drilling mud obtained April 1979 from a working drill rig in Mobile Bay, Alabama, and spiked in the laboratory with 0, 3, and 10 ppm ferrochrome lignosulfonate (FCLS) (Krone and Biggs, 1980). These muds were atypical in composition for discharge into marine waters. During the first week of exposure to drill mud + FCLS, corals increased their oxygen consumption and

ammonium excretion, relative to uncontaminated controls. Those corals exposed to the highest enrichments of FCLS demonstrated the greatest increases in respiration and excretion and also the largest variation in respiration and excretion between individual corals. Corals reached their highest average rates of respiration and excretion by the end of the first week and, after a secondary increase in excretion and respiration between days 10-13 which was most pronounced in those corals exposed to FCLS enrichment, leveled off at near-initial rates by the end of the second week. Analysis of variance demonstrated that oxygen consumption of FCLS-stressed corals was not statistically different from uncontaminated control corals. By contrast, ammonium excretion was significantly greater in FCLS-stressed corals than in uncontaminated control animals.

All corals exposed to FCLS reacted by reducing their degree of polyp expansion. Two of these, one exposed to 100 ppm drill mud + 3 ppm FCLS and the other to 100 ppm drill mud 10 ppm FCLS, became bacterially infected and showed local areas of polyp mortality as the experiment entered its second week. These were the two corals that had shown the most rapid and most consistent increases in excretion and respiration during the first week of exposure to FCLS.

When exposure to drill mud + FCLS was discontinued, respiration and excretion of surviving corals remained low and stable while their polyp activity returned to normal levels within 48 hours Thompson (1980).

4.4 SUMMARY

Petrazzuolo (1981) has reviewed those studies summarized in sections 4.2 and 4.3 as well as other studies. An environmental hazard assessment was carried out based on the literature review in support of the issuance of a general discharge permit for oil and gas drilling rigs in the Gulf of Mexico. The area covered by the general permit excludes areas adjacent to the Flower Garden Banks.

The estimates of the effect of drilling fluids and cuttings determined by Petrazzuolo (1981) are based on the combined results of two types of analysis. In the first type of analysis, acute lethal toxicity data were extrapolated to estimate the potential chronic effects after applying a safety factor of 0.01. These data were the results of 303 acute lethal toxicity tests conducted on 35 to 40 drilling fluids using 48 species of test animals. A second analysis utilized data on the effects of chronic (10 week) drilling fluid exposure on benthic recruitment and development in a flowthrough system. These data were used in conjunction with data from short-term, water column dispersion studies of the discharge plumes for

whole drilling fluids and the soluble and fine particulate fraction of the drilling fluids to estimate the potential hazard of the discharge in the environment.

Analysis by Petrazzuolo (1981) of the results of the acute toxicity data for the species and drilling fluids that have been tested to date yielded the following results:

Percentage of LC_{50} Values Exceeding the Given Concentration	Drilling Fluid Concentration (ppm)
50	100,000
83	10,000
97-99	1,000
all	100

These results are derived from the relative frequencies of LC_{50} values occurring within specified ranges of drilling fluid concentrations. The use of percentage frequencies instead of absolute frequencies of occurrence eliminates any bias in the resulting distribution that would tend to favor the sensitivities of species that have been tested most often.

The 96-hour LC_{50} value for the most sensitive species tested was 100 ppm. Utilizing dispersion data, a concentration of 100 ppm would be achieved within 100m of the discharge for whole muds and 1000m for the longer lasting soluble plume. For most species acute lethal effects would not be expected more than 15m from the discharge.

Estimates of the distance beyond which no chronic effects would result to water column organisms ranged from 40m to 1000m depending on the sensitivity of the species tested. Most species would be unaffected within 100m.

Estimates of effects on abundance of benthic organisms were as follows:

Distance (m)	Percent Reduction (excludes burial effects)
1-100	50
65-195	17
185-1100	2-10
1000-1400	No substantial effect

5.0 FUTURE DIRECTION OF THE EPA PROGRAM

At the present point in the EPA Drilling Fluids Hazard Assessment Program, initial results are becoming available. Additionally, several extensive literature reviews are in preparation by EPA and other agencies. While the results to date must be verified and placed in perspective by the work yet to be completed, enough is known from EPA, industry, and other agency research to establish the needs of the final year of the EPA program.

5.1 FACTORS AFFECTING THE FINAL YEAR OF THE EPA PROGRAM

Results of work involving transport and fate of discharged muds (exposure assessment) suggest that the majority of the mud may be deposited near the point of discharge. The visible plume that remains in the water column may constitute a relatively small amount of the total volume discharged. These findings, however, must be verified using better techniques that can overcome the hinderances and sampling problems associated with the pioneer studies.

Considerable laboratory work on the effects of drilling muds on marine organisms has been carried out by EPA, the oil industry, and other Federal agencies since the initiation of the EPA Drilling Fluids Hazard Assessment Program in 1975. The composition of drilling muds is becoming better understood. The range of toxicity of drilling muds is becoming established for the types of muds tested to date. Some bioaccumulation of barium and metals has been observed. With this expanding data base, it is now time to synthesize and review the data in order to develop an assessment of the drilling mud problem and the outline of a protocol for dealing with individual site-specific situations involving the discharge of drilling muds. Still needed as an input to this assessment is toxicity screening of a variety of muds representative of those used on the Outer Continental Shelf.

As part of the recent court settlement concerning oil and gas leasing on the Georges Bank, the Department of the Interior has been directed to respond to the research needs for this area. These needs are to be identified by the Biological Task Force, the existing interagency advisory body for environmental issues related to Georges Bank. EPA is a member of this committee. To avoid duplication of effort and in response to funding cutbacks within EPA, drilling fluid hazard assessments for th Georges Bank will now be one of the concerns to be dealt with by the Biological Task Force. For the Gulf of Mexico, an interagency five-year research plan is also being prepared to coordinate drilling-related studies. EPA can help determine research to be carried out through its membership on this committee. Also, monitoring programs required of industry to determine

compliance with discharge permit conditions will provide some additional data on muds in the marine environment.

5.2 STRATEGY FOR THE FINAL YEAR OF THE PROGRAM

The proposed strategy for the final year (fiscal year 1982) of the Drilling Fluids Hazard Assessment Program is given in Figure 5-1. The concentration will be on in-situ discharge plume studies and on laboratory screening of a variety of muds representative of drilling fluids that are being used or will be used on the Outer Continental Shelf. The results of these final studies, all other studies completed as part of the EPA program, and work carried out by other groups will lead to an adaptive environmental assessment model and a state-of-the-art document that will include guidance for assessing the effect of drilling fluid discharges in the marine environment.

The in-situ plume studies will include both exposure and effects assessments. The exposure work will be a continuation of the discharge plume transport studies by NOAA. Emphasis will be on predicting concentrations of drilling fluids that could occur under various discharge conditions from platforms. The effects assessment will be field studies focusing on the effects of drilling fluids on corals and benthic organisms.

The screening of muds typical of those used on the Outer Continental Shelf will use about 50 muds to be furnished by the Petroleum Equipment Supplies Association. These mud samples will be split with the oil industry. EPA and industry groups will then carry out the same kinds of chemical analyses and laboratory biological toxicity tests so that scientific results can be compared.

Synthesis activities will be undertaken in order to pull together the results of the overall EPA drilling fluids research program and the extensive data base developed by the oil industry and other Federal agencies since 1975. This activity will be accomplished by preparing an assessment document that summarizes and synthesizes what is known about the effects of drilling muds in marine environments. An Adaptive Environmental Assessment Workshop will contribute to this effort. Also included in the assessment document will be a protocol for applying the knowledge gained to the assessment and monitoring of individual site-specific situations involving the discharge of drilling muds.

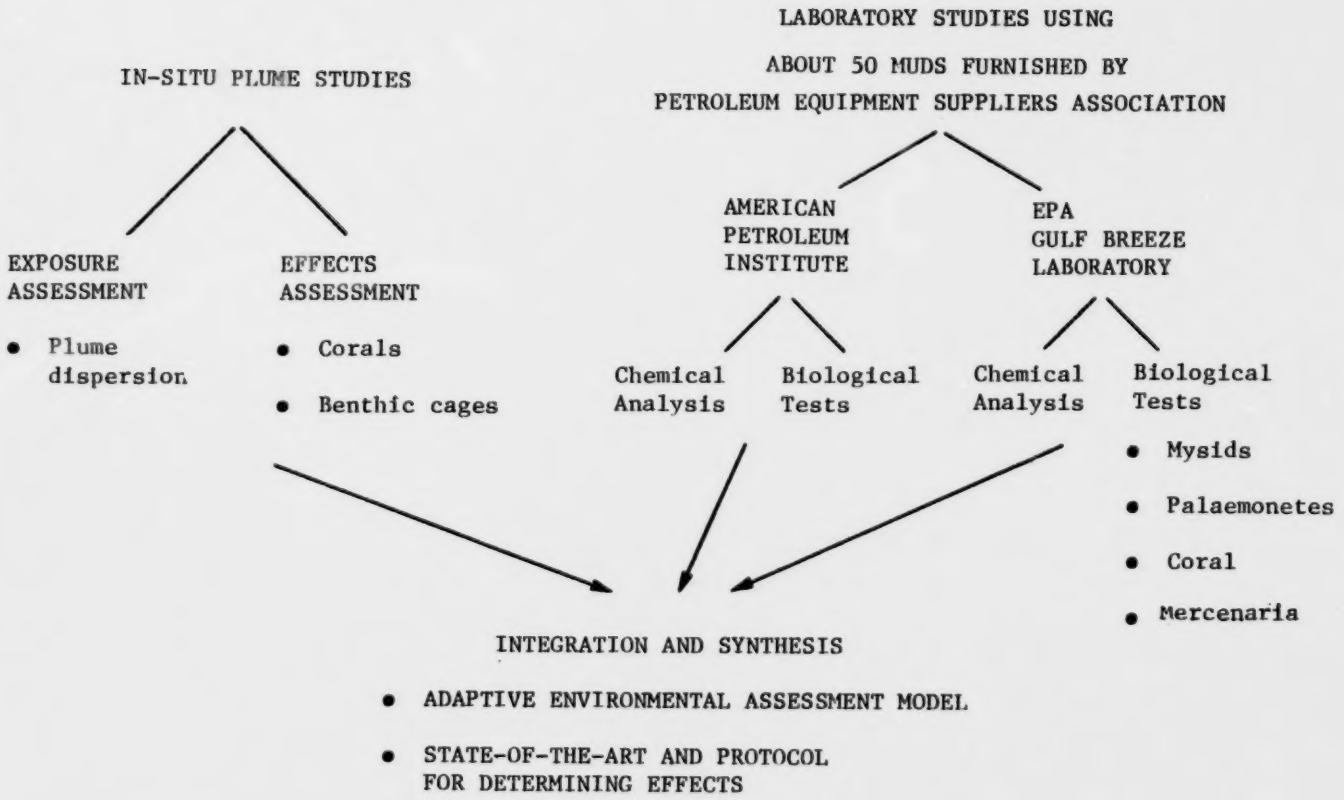

FIGURE 5-1
RESEARCH STRATEGY FOR THE FINAL YEAR OF THE DRILLING FLUIDS HAZARD ASSESSMENT PROGRAM

APPENDIX A

PROJECT DESCRIPTIONS

EPA DRILLING FLUIDS HAZARD ASSESSMENT PROGRAM

APPENDIX A-1

GENERIC STUDIES

Project Title: Drilling Fluid Reference Standards for Chemical Analysis

Performing Organization: U.S. National Bureau of Standards
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To develop and provide drilling fluid reference standards for use in characterization efforts and in a quality assurance program to improve and maintain reliability of measurements made on discharges from drilling and production operations.

Approach: (1) Obtain candidate reference material(s) from EPA-Gulf Breeze and assess the feasibility for preparing a dry mixture of four major drilling fluid components; (2) If step (1) proves feasibile, prepare a batch (i.e., grind, blend, sieve) of material and establish homogeneity; (3) Characterize the drilling fluid mixture for several trace elements to be determined by NBS and EPA-Gulf Breeze; (4) Package, label, and provide EPA-Gulf Breeze with drilling fluid reference standard for specified trace elements.

Output: Report on Reference Standards of Drilling Fluids
Delivery: 2-81

Project Title: Chemical Analysis of Drilling Fluids

Performing Organization: JRB Associates
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To provide support to the Environmental Research Laboratory at Gulf Breeze for organic analytical chemical analyses.

Approach: Analytical chemical services include the chemical characterization of drilling fluids used in exposure of test organisms, the accumulation of drilling fluid components in tissues of exposed organisms, and the uptake of particulate drilling fluid components in organisms.

Output: Analysis will be reported as part of the biological experiments for which support was provided. There will also be a final report on chemical analyses of drilling fluids.
Delivery: 6-81

Project Title: Chemical Analysis for Energy Program

Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: The purpose of this task is to provide organic analytical chemical support to aquatic toxicity tests at the Gulf Breeze Environmental Research Laboratory.

Approach: Analytical chemical services include development of methods for analysis, measurement of concentrations in flowing seawater, and determination of accumulation of concentrations in tissues of organisms utilized in experiments.

Output: Results of the chemical analyses will be reported as part of the study for which they were performed.

Delivery: 9-82

Project Title: Mixing Zone Definition for Nonbuoyant Discharges in Support of Section 403(c) of the Clean Air Act

Laboratory: Corvallis Environmental Research Laboratory

Objective: The objective of this research is to develop/revise mixing-zone calculation methods for industrial discharges. Emphasis will be given to those discharges containing fluids, emulsions, and suspensions heavier than marine water, or those which in general behave differently than the municipal wastes for which mathematical models and limited verification data are available.

Approach: Laboratory and field verification will be conducted to substantiate the level of confidence in predicting water quality characteristics for pollutants regulated by numerical criteria. Completion of this research will most likely result in a revision of the mixing zone definition requirements under 403(c).

Output: Report on mixing zone calculation (model) for those discharges containing fluids, emulsions, and suspensions heavier than marine water for which mathematical models of limited utility exist.
Delivery: 12-80

Output: Report on verification of model
Delivery: 9-81

Output: Report on application of the model to several situations.
Delivery: 6-82

Project Title: Toxic, Sublethal and Latent Effects of Selected Petroleum Hydrocarbons and Barium Sulfate on Marine Organisms

Performing Organization: University of West Florida
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To determine if drilling fluid components have adverse affects on marine organisms with emphasis on crustaceans.

Approach: Laboratory tests are used to see if toxic effects and bioaccumulation occurs.

Output: Final report, journal articles and book
Delivery: 9-80

Project Title: Behavioral Assays for the Effects of Drilling Muds on Marine Animals

Performing Organization: University of West Florida
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To develop and test a device for measuring the behavioral response of the scallop to drilling fluids.

Approach: A device capable of recording bivalve opening, pumping, and escape attempts was developed.

Output: Final report
Delivery: 9-80

Project Title: Laboratory and Field Studies of Used Drilling Fluids and Fluid Formulation Components on Benthic Communities

Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Develop and apply methods for determining the effect of diesel oil on a marine off-shore benthic community microcosm.

Approach: Utilize methods developed at the Gulf Breeze Laboratory and methods developed at the off-shore platform (Stage I) to determine impact of diesel oil on a developing benthic community microcosm. The variation, if any, between controls and experimentals with respect to numbers and kinds of individuals as well as phyla will be observed.

Output: Final report and scientific paper
Delivery: 9-80

Project Title: Offshore Pollutant Effects Program*

Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To determine the environmental effects of offshore oil extraction. In order to simulate the conditions of the marine environment, the Stage I offshore platform owned and maintained by the Naval Coastal Systems Laboratory, Panama City, Florida, will be used.

Approach: the Stage I facility and support for its operation will be provided by the Navy.

Output: Conclude use of facility
Delivery: 10-81

*This project has been suspended because of storm damage until restoration funds become available.

Project Title: The Effect of Drilling Mud on Marine Organisms

Performing Organization: Florida State University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To provide support for the operation of Stage I, and offshore research laboratory near Panama City, Florida.

Approach: Specific tasks include the developments of a flowing seawater aquatic toxicology testing laboratorys, collect organisms for testing, collaborate with EPA and extramural researchers in the performance of toxicity tests, and logistic support.

Output: Final project report
Delivery: 7-80

Project Title: Effects of Drilling Mud Constituents on the Sedimentary Microflora and the Base of the Marine Benthic Food Web

Performing Organization: Florida State University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Develop and apply methods to assess environmental effect of offshore oil and gas exploration on marine organisms.

Approach: Determine effects that result from exposure of marine organisms.

Output: Journal article on impact on microflora.
Delivery: 10-80

Output: Final project report on methodology and effects
Delivery: 10-80

Project Title: Effects of Soluble Fractions of Drilling Fluids on Larval Development and Behavior of Callinectes sapidus and Rhithropanopeus harrissii

Performing Organization: Duke University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: The research includes measurements of drilling fluid effects on (a) long-term development of crab larvae, (b) short-term development of specific larval life stages, (c) swimming speed of larvae, and (d) positive or negative phototaxis of the larvae.

Approach: Laboratory studies will be carried out.

Output: Final report
Delivery: 11-81

Project Title: Effects of Drilling Fluids on Embryo Development

Performing Organization: Trinity College
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To test for teratogenic effects of drilling fluids

Approach: The effects of drilling fluids on the developmental stages of the embryos of fish and echinoderms will be determined.

Output: Final report
Delivery: 5-82

Project Title: Effects of Barium Sulfate on Fertilization of Early Development

Performing Organization: Florida State University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: The effects of barium sulfate, a principal component of drilling fluids, on sea urchin gametes and embryos will be assessed. The project will characterize the cellular events which are disturbed by barium sulfate and will determine the effective concentrations necessary to induce these perturbations.

Approach: Sea urchin eggs and sperm will be exposed to solutions containing barium. Barium is a periodic analog of calcium, which is important as a mediator of such cellular functions as fertilization, cell division and later development. The project will characterize the cellular events which are disturbed by barium sulfate, a major component of fluids used in oil and gas well-drilling.

Output: Final report
Delivery: 3-82

Project Title: Completion of Hazard Assessment Program

Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To synthesize existing literature and conduct a limited amount of research on the effects of the fluids on selected marine organisms.

Approach: Principal efforts will be directed toward completion of the five-year Drilling Fluids Hazard Assessment Program. A state-of-the-art document will be prepared on the impact of drilling fluids on marine organisms, which will include a hazard assessment and protocol for measuring potential impact of drilling fluids. Bioassay screening of the impact of "down-hole" and other drilling fluids on selected marine organisms will also be carried out.

Output: State-of-the-art document
Delivery: 9-82

Output: Final report of the impact of drilling fluid samples
Delivery: 9-82

Project Title: Literature Review of Environmental Effects of Well-Drilling Chemicals

Performing Organization: Battelle-Columbus Laboratory
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Prepare a review of available literature, published and unpublished, on the origins, fate and effects of chemicals discharged from oil and gas drilling operation into the marine environment.

Output: Final report - annotated bibliography
Delivery: 10-81

Project Title: Symposium on the Effects of Chemicals Used in Offshore Oil and Gas Drilling Operation on Marine Organisms

Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Disseminate state-of-the-art information on the effects of oil and gas drilling activities on organisms and ecosystems to industry, government, the academic community and the general public.

Approach: Establish program committee for symposium. Advertise meeting, select papers and session chairman, hold meeting, publish proceedings. In parallel with the above activities, prepare annotated bibliography.

Output: Symposium completed
Delivery: 2-80

Output: Report and technical assistance to EPA and Region I and VI
Delivery: 12-80

Output: Annotated bibliography
Delivery: 12-81

Output: Final project report
Delivery: 12-82

APPENDIX A-2

FLOWER GARDEN BANKS

GULF OF MEXICO

Project Title: Assessment of Exposure of the Ecosystem of the Texas Flower Gardens to Pollutants Originating from Oil and Gas Drilling Rigs

Performing Organization: National Oceanic and Atmospheric Administration
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To strengthen the scientific foundation of the estimates or prediction of the dosage of drilling fluids discharged into the water near the Flower Garden Banks.

Approach: Acoustical, particulate and physical oceanographic measurements of the dosage of shunted drilling fluids from a well near the Flower Garden Banks will be made. A predictive model for drilling mud dispersion processes will be developed from these data.

Output: Final report
Delivery: 9-82

Project Title: Offshore Laboratory Studies of the Impacts of Used Drilling Fluids on Behavior of Corals Representative of the Flower Garden Banks

Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Develop and apply methods to determine lethal and sub-lethal effectes of drilling fluids and this components on corals.

Approach: Expose corals to drilling fluids and through time-lapse movies, observe the rates of sediment removal or polps contration. A mud-profile (muds from various depths of a working well) will be used in the experiments. The project also provides fiscal support for using Stage I.

Output: Final report
Delivery: 9-82

Project Title: Effects of Drilling Fluids and Oil on Corals Occupying Hard-Bank Communities

Performing Organization: Texas A&M University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Determine if drilling fluids have adverse effects on adult reef building corals.

Approach: Various corals were tested to determine the toxicity of a variety of drilling fluids to corals under laboratory and field conditions.

Output: Final report
Delivery: 4-79

Project Title: Biochemical Analyses on Coral and Other Invertebrate Metabolic Activity and Nutritional Status with Exposure to Oil and Gas Drilling Mud

Performing Organization: Florida State University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Develop and test biochemical measures of the effects of drilling muds on: (1) The coral-zooxanthellae interaction using lipid analysis; (2) The nutritional status with the triglyceride, wax ester, phospholipid ration; (3) The metabolic status of corals using the lipid analysis and GC/MS.

Approach: Expose corals and perform chemical analyses

Output: Final report on impact of drilling muds on biochemical aspects of corals
Delivery: 9-82

Project Title: Effects of Drilling Mud on Corals: Some Biochemical and Neurochemical Aspects

Performing Organization: Louisiana State University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To study the effect of drilling mud treatment on some biochemical and neurochemical aspects of coral physiology. Specifically, these studies will include the evaluation of protein, nucleic acid, energy and catacholamine metabolism.

Approach: Radioactive amino acids will be added to corals and the incorporation of the amino acid into protein will be measured by scintillation counting. Thin layer chromatography and radioenzyme assay will be used to measure various enzyme activities and the effects of drilling mud on them.

Output: Final project report on biochemical and neurochemical effect of drilling fluids on corals.
Delivery: 8-81

Project Title: Effects of Offshore Oil and Gas Drilling on Reef Building Corals

Performing Organization: Texas A and M University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Determine the effects of chemicals used in offshore oil and gas drilling activities on reef-building corals.

Approach: Expose corals to drilling fluids at the EPA-leased Navy platform at Panama City, Florida, and measure effects by time-lapse photography.

Output: Final Report
Delivery: 6-82

Project Title: Effects of Oil Drilling Muds on the Physiology and Nutritional Status of Texas Flower Garden Reef Coral

Performing Organization: Florida State University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: 1) Determine the effects of various concentrations of whole drilling mud on respiration, nitrogen excretion and calcification in a reef coral. 2) Determine the effects of various concentration of whole drilling mud on the nutritional states of reef corals. 3) Send exposed corals to other investigators for complementary biochemical and histopathological investigations.

Approach:

Output: Final project report
Delivery: 5-81

Project Title: Physical and Chemical Effects of Drill Mud on Coral Skeletons

Performing Organization: Nova University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To measure the physical and chemical record in coral skeletons using density of minerals deposited in the skeleton during periods of growth.

Approach: X-radiography will be used to determine the density gradients in the coral skeletons. Also, in-situ cores of coral heads will be taken and x-radiography will be used to examine those corals.

Output: Final report
Delivery: 6-82

Project Title: Comparison of Reef Fish Populations at the Flower Garden Banks and at Oil and Gas Drilling Platforms

Performing Organization: National Oceanic and Atmospheric Administration
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To evaluate the impact of offshore drilling activities on fish within a unique coral reef ecosystem in the northwestern Gulf of Mexico.

Approach: Offshore drilling structures provide an artificial habitat for fish and bring them into contact with point source pollutants. Such contaminants may be taken up by reef fishes or may cause mortality or histopathological effects, suppress food organism populations, or affect growth, reproductive processes, recruitment, behavior, movements and migrations. The goal of this project is to assess the biological characteristics of natural reef fish populations and compare them with those of reef fish populations associated with oil and gas fields in the northwestern Gulf of Mexico.

Output: Report covering the movements, migration, recruitment, and standing stocks of reef fishes by catch-effort and mark-recapture methods.
Delivery: 12-82

Output: Report describing the standing stocks, distribution, and community structure of benthic macro-infauna in relation to drilling operations.
Delivery: 12-82

Output: Report presenting the histopathology of reef fishes in relation to drilling operations.
Delivery: 12-82

Output: Report that describes the microbial communities of reef fishes, drilling plumes, nepheloid layers and surficial sediments
Delivery: 12-82

Output: Report that describes the movements, migration, recruitment, and standing stocks of reef fishes by remote sensing assessments
Delivery: 12-82

Project Title: Toxic and Sublethal Effects of Waste Drilling Muds and Certain Chromium Compounds in Crustaceans

Performing Organization: University of West Florida
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: The project will investigate the effects of drilling muds and their components on crustaceans.

Approach: Laboratory experiments will be used to predict effects.

Output: Report on whole drilling mud effects
Delivery: 3-81

Output: Report on effects of drilling mud components
Delivery: 3-82

Output: Final project report
Delivery: 3-83

Project Title: Developments of Components of a Monitoring System - (I) Tethered Cage

Performing Organization: National Oceanic and Atmospheric Administration
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To develop a tethered cage that can maintain its position in the thermocline.

Approach: The cage would be capable of maintaining its position in that thermocline and would be fitted with special devices for remotely monitoring the health status of the caged animals.

Output: Preliminary engineering design package
Delivery: 9-80

Output: Deicsion on final design
Delivery: 10-80

Output: Complete laboratory system
Delivery: 5-81

Output: Complete field testing
Delivery: 8-81

Output: Final report
Delivery: 9-81

Project Title: Development of Components of a Monitoring System - (II) Evaluation of Devices and Materials for Seawater Chemical Sample Collection-Preconcentration, and Analysis

Performing Organization: National Oceanic and Atmospheric Administration
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: The program had three objectives: Determination of performance and contamination characteristics of existing monitoring systems, specifically those that will be used in Texas Flower Gardens research; evaluation of preconcentration materials; and, development of laboratory analytical techniques.

Approach: Equipment will be evaluated and techniques developed.
Output: Complete evaluation of the performance and contamination characteristics of the trace metal sampler.
Delivery: 1-81

Output: Complete the characterization of the performance and measurement uncertainties of the in situ monitoring system.
Delivery: 8-81

Output: Complete the determination of the performance/contamination characteristics of a pump sampling for trace metal analysis.
Delivery: 1-82

Output: Complete the determination of the performance/contamination characteristics of pump sampling system for organic analysis.
Delivery: 1-83

Project Title: Development of Components of a Monitoring System - (III) Automated Sampler for Trace Organics in Marine Waters

Performing Organization: National Oceanic and Atmospheric Administration
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To develop a self-contained automated sampler for in-situ collection of trace organic chemicals in marine waters.

Approach: The sampler should be able to collect particulate and dissolved samples and preserve both in uncontaminated condition until removal for subsequent analysis, presumably by GC/MS. The sampler should be programmable in terms of sampling intervals and frequencies and the collected samples should be ready for analysis without significant additional handling or processing.

Output: Final report on shipboard prototype
Delivery: 1-82

Output: Final report on deployable system
Delivery: 10-83

Project Title: New Methodologies for Measuring Energy-Related Consent Decree Toxic Compounds in the Marine Environment

Performing Organization: National Oceanic and Atmospheric Administration
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: This project has three subobjectives: (1) validated methods for separating trace organic marine pollutants into major chemical classes and removal of natural marine organics that interfere with pollutant analysis; (2) validated techniques for final detection, identification and measurement of individual trace organic marine pollutants; and (3) identification of potentially hazardous organic pollutants from marine water samples from the Texas Flower Gardens as well as from areas near various ocean outfalls.

Approach: Validate methods and techniques and identify potentially hazardous organic pollutants.

Output: Report on filter and sorbent components for sampling trace organic pollutants in marine waters.
Delivery: 9-81

Output: Report or peer-reviewed journal article on separation schemes for major classes and subclasses of trace polar and nonpolar organic marine pollutants.
Delivery: 9-81

Output: Report or peer-reviewed journal article on multiple analytical methods for determining ppb-ppt levels of individual polar organic marine pollutants.
Delivery: 9-81

Output: Report or peer-reviewed journal article on inventory of organic marine pollutants, including those not known, that could have a potentially adverse effect on Flower Garden Banks.
Delivery: 9-82

Project Title: Adaptive Environmental Assessment Workshop on Drilling Mud Disposal

Performing Organization: U.S. Department of the Interior
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: The Adaptive Environmental Assessment Group of the Department of the Interior will provide staff support to EPA in conducting a workshop on an integrated approach to regulations of drilling and disposal.

Approach: The approach to provide this assistance will consist of (1) a scoping meeting with key EPA personnel for identification of the specific problem to be addressed by hypothetical model, and (2) providing the staff assistance and guidance in conducting an EPA sponsored AEA modeling workshop.

Output: Workshop report.
Delivery: 9-82

Project Title: Identification of Macroinfauna from Experiments Conducted at the U.S. Navy Platform "Stage I"

Performing Organizaton: VITRO
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Identify benthic organisms in support of "Stage I" research on the effects of drilling fluids on marine organisms.

Approach: Identification will be performed using state-of-the-art taxonomic procedures.

Output: Final project report
Delivery: 12-81

Project Title: Technical Assistance to EPA Region VI

Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: The EPA Gulf Breeze Environmental Research Laboratory will provide technical assistance to EPA Region VI on NPDES permitting of discharges from offshore oil and gas drilling activities.

Approach: Perform hazard assessment based on exposure assessment and effects assessment. This project will provide a continuing source of technical assistance to EPA Program Offices and Regional Offices.

Output: Permit review as needed
Delivery: 12-83 - Terminate ongoing technical assistance

APPENDIX A-3

GEORGES BANK

GULF OF MAINE

Project Title: The Erodibility of Drilling Muds Deposited on the Seafloor

Performing Organization: Yale University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To explore the erodibility of drilling muds in different ecological conditions.

Approach: Laboratory flume studies and field observation will be used to determine drilling mud stability.

Output: Final report on erodibility of drilling muds of the seafloor
Delivery: 3-82

Project Title: Effects of Drilling Mud on Adult American Lobster

Performing Organization: Boston University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To determine the effects of drilling muds on the American Lobster

Approach: The effects of drilling muds on feeding, molting, mating, predator escape, shelter behavior, and substrate selection of lobsters will be determined by controlled laboratory experiments and seminatural environment and field observations.

Output: Final effects assessment report
Delivery: 3-82

Project Title: Drilling Fluid Effects to Developmental Stages of the American Lobster

Performing Organization: Woods Hole Oceanographic Institute
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Predict the impact of drilling operations for oil exploration on populations of the American Lobster (Homarus americanus).

Approach: The effects of used, whole drilling fluids on larval and postlarval stages of the lobster will be assessed.

Output: Final report
Delivery: 9-81

Project Title: Feeding, Reproduction and Habitat Selection of Lobster Homarus americanus - Effects of Drilling Mud in Laboratory and Field Situations

Performing Organization: Boston University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Determine the effects, if any, of drilling fluids pollutants on behavior of the American Lobster.

Approach: Field, laboratory and neurophysiological studies of the behavior of larval and young lobsters and the relation to exposure to drilling fluids.

Output: Final report
Delivery: 6-81

Project Title: The Effects of Drilling Muds on the Behavior and Benthic Ecology of Three Gadid Species

Performing Organization: National Oceanic and Atmospheric Administration
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: To examine the effects of drilling on juveniles.

Approach: There will be two major phases of the study, (1) establishment of the normal baseline of settling behavior of the three species and their patterns of shelter acquisition and feeding exhibited during the benthic, juvenile stages, and (2) alterations in the behavioral baselines following pollutant contamination from drilling muds.

Output: Final report
Delivery: 12-81

Project Title: A Study of the Impact of Discharged Drilling Fluid on the Organisms of Georges Bank

Performing Organization: New England Aquarium
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: The objectives of the proposed research are to expand the data base on the effects of drilling fluids on the fauna of Georges Bank and to characterize toxic consitituents of drilling fluids.

Approach: Laboratory approach will involve toxicity tests on marine organisms

Output: Final report on toxicity tests
Delivery: 9-82

Project Title: The Impact of Drilling Muds on Standing Stocks and Metabolic Activities of Sediment Bacteria

Performing Organization: Wayne State University
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: This project will examine the impact of drilling mud on bacteria populations.

Approach: Bacterial populations from sediment samples will be counted and their growth rates determined.

Output: Final Report
Delivery: 3-82

Project Title: Benthic Communities and Drilling Fluid Effects on the Conditions for Larval Settlement on the Georges Bank

Performing Organization: U.S. Geological Survey
Responsible Laboratory: Gulf Breeze Environmental Research Laboratory

Objective: Develop a technique for studying the effects of drilling muds and fluids on larval settlement on benthic organisms.

Approach: Traps will be used for *in situ* experiments on the effects of drilling fluids on larval settlement.

Output: Final report
Delivery: 6-81

APPENDIX B

SECTIONS 402 AND 403

CLEAN WATER ACT (PL92-500)

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

Sec. 402. (a) (1) Except as provided in sections 318 and 404 of this Act, the Administrator may, after opportunity for public hearing, issue a permit for the discharge of any pollutant, or combination of pollutants, notwithstanding section 301 (a), upon condition that such discharge will meet either all applicable requirements under sections 301, 302, 306, 307, 308, and 403 of this Act, or prior to the taking of necessary implementing actions relating to all such requirements, such conditions as the Administrator determines are necessary to carry out the provisions of this Act.

(2) The Administrator shall prescribe conditions for such permits to assure compliance with the requirements of paragraph (1) of this subsection, including conditions on data and information collection, reporting, and such other requirements as he deems appropriate.

(3) The permit program of the Administrator under paragraph (1) of this subsection, and permits issued thereunder, shall be subject to the same terms, conditions, and requirements as apply to a State permit program and permits issued thereunder under subsection (b) of this section.

(4) All permits for discharges into the navigable waters issued pursuant to section 13 of the Act of March 3, 1899, shall be deemed to be permits issued under this title, and permits issued under this title shall be deemed to be permits issued under section 13 of the Act of March 3, 1899, and shall continue in force and effect for their term unless revoked, modified, or suspended in accordance with the provisions of this Act.

(5) No permit for a discharge into the navigable waters shall be issued under section 13 of the Act of March 3, 1899, after the date of enactment of this title. Each application for a permit under section 13 of the Act of March 3, 1899, pending on the date of enactment of this Act shall be deemed to be an application for a permit under this section. The Administrator shall authorize a State, which he determines has the capability of administering a permit program which will carry out the objective of this Act, to issue permits for discharges into the navigable waters within the jurisdiction of such State. The Administrator may exercise the authority granted him by the preceding sentence only during the period which begins on the date of enactment of this Act and ends either on the ninetieth day after the date of the first promulgation of guidelines required by section 304 (h) (2) of this Act, or the date of approval by the Administrator of a permit program for such State under subsection (b) of this section, whichever date first occurs, and no such authorization to a State shall extend beyond the last day of such period. Each such permit shall be subject to such conditions as the Administrator determines are necessary to carry out the provisions of this Act. No such permit shall issue if the Administrator objects to such issuance.

(b) At any time after the promulgation of the guidelines required by subsection (h) (2) of section 304 of this Act, the Governor of each State desiring to administer its own permit program for discharges into navigable waters within its jurisdiction may submit to the Administrator a full and complete description of the program it proposes to establish and administer under State law or under an interstate compact. In addition, such State shall submit a statement from the attorney general (or the attorney for those State water pollution control agencies which have independent legal counsel), or from the chief legal officer in the case of an interstate agency, that the laws of such State, or the interstate compact, as the case may be, provide adequate authority to carry out the described program. The Administrator shall approve each such submitted program unless he determines that adequate authority does not exist:

(1) To issue permits which—

(A) apply, and insure compliance with, any applicable requirements of sections 301, 302, 306, 307, and 403;

(B) are for fixed terms not exceeding five years; and

(C) can be terminated or modified for cause including, but not limited to, the following:

(i) violation of any condition of the permit;

(ii) obtaining a permit by misrepresentation, or failure to disclose fully all relevant facts;

(iii) change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge;

(D) control the disposal of pollutants into wells;

(2) (A) To issue permits which apply, and insure compliance with, all applicable requirements of section

308 of this Act, or

(B) To inspect, monitor, enter, and require reports to at least the same extent as required in section 308 of this Act;

(3) To insure that the public, and any other State the waters of which may be affected, receive notice of each application for a permit and to provide an opportunity for public hearing before a ruling on each such application;

(4) To insure that the Administrator receives notice of each application (including a copy thereof) for a permit;

(5) To insure that any State (other than the permitting State), whose waters may be affected by the issuance of a permit may submit written recommendations to the permitting State (and the Administrator) with respect to any permit application and, if any part of such written recommendations are not accepted by the permitting State, that the permitting State will notify such affected State (and the Administrator) in writing of its failure to so accept such recommendations together with its reasons for so doing;

(6) To insure that no permit will be issued if, in the judgment of the Secretary of the Army acting through the Chief of Engineers, after consultation with the Secretary of the department in which the Coast Guard is operating, anchorage and navigation of any of the navigable waters would be substantially impaired thereby;

(7) To abate violations of the permit or the permit program, including civil and criminal penalties and other ways and means of enforcement.

(8) To insure that any permit for a discharge from a publicly owned treatment works includes conditions to require the identification in terms of character and volume of pollutants of any significant source introducing pollutants subject to pretreatment standards under section 307 (b) of this Act into such works and a program to assure compliance with such pretreatment standards by each such source, in addition to adequate notice to the permitting agency of (A) new introductions into such works of pollutants from any source which would be a new source as defined in section 306 if such source were discharging pollutants. (B) new introductions of pollutants into such works from a source which would be subject to section 301 if it were discharging such pollutants, or (C) a substantial change in volume or character of pollutants being introduced into such works by a source introducing pollutants into such works at the time of issuance of the permit. Such notice shall include information on the quality and quantity of effluent to be introduced into such treatment works and any anticipated impact of such change in the quantity or quality of effluent to be discharged from such publicly owned treatment works; and

(9) To insure that any industrial user of any publicly owned treatment works will comply with sections 204 (b), 307, and 308.

(c) (1) Not later than ninety days after the date on which a State has submitted a program (or revision thereof) pursuant to subsection (b) of this section, the Administrator shall suspend the issuance of permits under subsection (a) of this section as to those navigable waters subject to such program unless he determines that the State permit program does not meet the requirements of subsection (b) of this section or does not conform to the guidelines issued under section 304 (i) (2) of this Act. If the Administrator so determines, he shall notify the State of any revisions or modifications necessary to conform to such requirements or guidelines.

(2) Any State permit program under this section shall at all times be in accordance with this section and guidelines promulgated pursuant to section 304 (h) (2) of this Act.

(3) Whenever the Administrator determines after public hearing that a State is not administering a program approved under this section in accordance with requirements of this section, he shall so notify the State and, if appropriate corrective action is not taken within a reasonable time, not to exceed ninety days, the Administrator shall withdraw approval of such program. The Administrator shall not withdraw approval of any such program unless he shall first have notified the State, and made public, in writing, the reasons for such withdrawal.

(d) (1) Each State shall transmit to the Administrator a copy of each permit application received by such State and provide notice to the Administrator of every action related to the consideration of such permit application, including each permit proposed to be issued by such State.

(2) No permit shall issue (A) if the Administrator within ninety days of the date of his notification under subsection (b) (5) of this section objects in writing to the issuance of such permit, or (B) if the Administrator within ninety days of the date of transmittal of the proposed permit by the State objects in writing to the issuance of such permit as being outside the guidelines and requirements of this Act. Whenever the Administrator objects to the issuance of a permit under this paragraph such written objection shall contain a statement of the reasons for such objection and the effluent limita-

tions and conditions which such permit would include if it were issued by the Administrator.

(3) The Administrator may, as to any permit application, waive paragraph (2) of this subsection.

(4) In any case where, after the date of enactment of this paragraph, the Administrator, pursuant to paragraph (2) of this subsection, objects to the issuance of a permit, or request of the State, a public hearing shall be held by the Administrator on such objection. If the State does not resubmit such permit revised to meet such objection within 30 days after completion of the hearing, or, if no hearing is requested within 90 days after the date of such objection, the Administrator may issue the permit pursuant to subsection (a) of this section for such source in accordance with the guidelines and requirements of this Act.

(e) In accordance with guidelines promulgated pursuant to subsection (h) (2) of section 304 of this Act, the Administrator is authorized to waive the requirements of subsection (d) of this section at the time he approves a program pursuant to subsection (b) of this section for any category (including any class, type, or size within such category) of point sources within the State submitting such program.

(f) The Administrator shall promulgate regulations establishing categories of point sources which he determines shall not be subject to the requirements of subsection (d) of this section in any State with a program approved pursuant to subsection (b) of this section. The Administrator may distinguish among classes, types, and sizes within any category of point sources.

(g) Any permit issued under this section for the discharge of pollutants into the navigable waters from a vessel or other floating craft shall be subject to any applicable regulations promulgated by the Secretary of the Department in which the Coast Guard is operating, establishing specifications for safe transportation, handling, carriage, storage, and stowage of pollutants.

(h) In the event any condition of a permit for discharges from a treatment works (as defined in section 212 of this Act) which is publicly owned is violated, a State with a program approved under subsection (b) of this section or the Administrator, where no State program is approved or where the Administrator determines pursuant to section 309(a) of this Act that a State with an approved program has not commenced appropriate enforcement action with respect to such permit, may proceed in a court of competent jurisdiction to restrict or prohibit the introduction of any pollutant into such treatment works by a source not utilizing such treatment works prior to the finding that such condition was violated.

(i) Nothing in this section shall be construed to limit the authority of the Administrator to take action pursuant to section 309 of this Act.

(j) A copy of each permit application and each permit issued under this section shall be available to the public. Such permit application or permit, or portion thereof, shall further be available on request for the purpose of reproduction.

(k) Compliance with a permit issued pursuant to this section shall be deemed compliance, for purposes of sections 309 and 505, with sections 301, 302, 306, 307, and 403, except any standard imposed under section 307 for a toxic pollutant injurious to human health. Until December 31, 1974, in any case where a permit for discharge has been applied for pursuant to this section, but final administrative disposition of such application has not been made, such discharge shall not be a violation of (1) section 301, 306, and 402, of this Act, or (2) section 13 of the Act of March 3, 1899, unless the Administrator or other plaintiff proves that final administrative disposition of such application has not been made because of the failure of the applicant to furnish information reasonably required or requested in order to process the application. For the 180-day period beginning on the date of enactment of the Federal Water Pollution Control Act Amendments of 1972, in the case of any point source discharging any pollutant or combination of pollutants immediately prior to such date of enactment which source is not subject to section 13 of the Act of March 3, 1899, the discharge by such source shall not be a violation of this Act if such a source applies for a permit for discharge pursuant to this section within such 180-day period.

(l) The Administrator shall not require a permit under this section, for discharge composed entirely of return flows from irrigated agriculture, nor shall the Administrator directly or indirectly, require any State to require such a permit.

[*Editor's note:* SEC. 54(c) (2) of the Clean Water Act of 1977 says:

"Any State permit program approved under section 402 of the Federal Water Pollution Control Act before the date of enactment of the Clean Water Act of 1977, which requires modification to conform to the amendment made by paragraph (1) of this subsection, shall not be required to be modified before the end of the one year period which begins on the date of enactment of the Clean Water Act of 1977 unless in order to make the required modification a State must amend or enact a law in which case such modification shall not be required for such State before the end of the two year period which begins on such date of enactment."]

OCEAN DISCHARGE CRITERIA

Sec. 403. (a) No permit under section 402 of this Act for a discharge into the territorial sea, the waters of the contiguous zone, or the oceans shall be issued, after promulgation of guidelines established under subsection (c) of this section, except in compliance with such guidelines. Prior to the promulgation of such guidelines, a permit may be issued under such section 402 if the Administrator determines it to be in the public interest.

(b) The requirements of subsection (d) of section 402 of this Act may not be waived in the case of permits for discharges into the territorial sea.

(c) (1) The Administrator shall, within one hundred and eighty days after enactment of this Act (and from

time to time thereafter), promulgate guidelines for determining the degradation of the waters of the territorial seas, the contiguous zone, and the oceans, which shall include:

(A) the effect of disposal of pollutants on human health or welfare, including but not limited to plankton, fish, shellfish, wildlife, shorelines, and beaches;

(B) the effect of disposal of pollutants on marine life including the transfer, concentration, and dispersal of pollutants or their byproducts through biological, physical, and chemical processes; changes in marine ecosystem diversity, productivity, and stability; and species and community population changes;

(C) the effect of disposal, of pollutants on esthetic, recreation, and economic values;

(D) the persistence and permanence of the effects of disposal of pollutants;

(E) the effect of the disposal at varying rates, of particular volumes and concentrations of pollutants;

(F) other possible locations and methods of disposal or recycling of pollutants including land-based alternatives; and

(G) the effect on alternate uses of the oceans, such as mineral exploitation and scientific study.

(2) In any event where insufficient information exists on any proposed discharge to make a reasonable judgment on any of the guidelines established pursuant to this subsection no permit shall be issued under section 402 of this Act.

APPENDIX C

CALCULATION OF VOLUME OF DRILLING MUD DISCHARGED TO THE MARINE ENVIRONMENT DURING 1980

CALCULATION OF VOLUME OF DRILLING FLUIDS RELEASED TO THE MARINE ENVIRONMENT DURING 1979

The drilling fluids that are discharged within the marine environment typically are water-based slurries containing clays and various chemical and mineral additives. The specific formulations used in oil and gas exploration activities vary widely, although most contain barite (barium sulfate) for density control and low concentrations of sodium hydroxide, chrome lignosulfate, lignite and other chemicals to control viscosity, fluid loss, corrosion and other mud properties (Ayers, 1980).

These materials are released at drilling rig platforms both as relatively small-volume operational discharges and as infrequent large-volume bulk discharges. It is estimated that a total volume of 10,000 to 30,000 barrels of mud, containing 20 to 30 percent solids, are discharged over the life of a typical well (Ayers, 1980). Since the total number of wells within the OCS increased by 1,519 from 1978 to 1979 (U.S. Geological Survey, 1980), it is roughly estimated that a total of 15 million to 46 million barrels of drilling fluid were discharged into the marine environment during 1979. This is about 2.4 million to 7.1 million yd^3 (1.8 million to 5.4 million m^3).

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